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1989 Annual Tropical Cyclone Report

U. S. NAVAL OCEANOGRAPHY COMMAND CENTER
JOINT TYPHOON WARNING CENTER
COMNAVMARIANAS BOX 12
FPO SAN FRANCISCO, CA 96630-2926

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COMMANDING OFFICER

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LIEUTENANT COLONEL, UNITED STATES AIR FORCE
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FOREWORD

The Annual Tropical Cyclone Report is prepared by the staff of the Joint Typhoon Warning Center (JTWC), a combined Air Force/Navy organization operating under the command of the Commanding Officer, U.S. Naval Oceanography Command Center/Joint Typhoon Warning Center, Guam. JTWC was established 1 May 1959 when USCINCPAC directed USCINCPACFLT to provide a single tropical cyclone warning center for the western North Pacific region. The operations of JTWC are guided by CINCPACINST 3140.1T.

The mission of the Joint Typhoon Warning Center is multi-faceted and includes:

1. Continuous monitoring of all tropical weather activity in the Northern and Southern Hemispheres, from 180 degrees longitude westward to the east coast of Africa, and the prompt issuance of appropriate advisories and alerts when tropical cyclone development is anticipated.

2. Issuing warnings on all significant tropical cyclones in the above area of responsibility.

3. Determination of requirements for tropical cyclone reconnaissance and assignment of appropriate priorities.

4. Post-storm analysis of all significant tropical cyclones occurring within the western North Pacific and North Indian Oceans, which includes an in-depth analysis of tropical cyclones of note and all typhoons.

5. Cooperation with the Naval Oceanographic and Atmospheric Research Laboratory (NOARL), Monterey, California, on the operational evaluation of tropical cyclone models and forecast aids, and the development of new techniques to support operational forecast scenarios.

Satellite imagery used throughout this report represents data obtained by the DMSP network. The personnel of Detachment 1, 1WW, collocated with JTWC at Nimitz Hill, Guam, coordinate the satellite acquisitions and tropical cyclone reconnaissance with the following units:

Det 4, 20WS, Hickam AFB, Hawaii

Det 5, 20WS, Clark AB, Republic of the Philippines

Det 8, 20WS, Kadena AB, Japan

Det 15, 30WS, Osan AB, Korea

Air Force Global Weather Central, Offutt AFB, Nebraska

In addition, the Naval Oceanography Command Detachment, Diego Garcia, and Defense Meteorological Satellite Program (DMSP) equipped U.S. Navy ships have been instrumental in providing vital fixes of tropical cyclones in the Indian Ocean from satellite data.

Should JTWC become incapacitated, the Alternate Joint Typhoon Warning Center (AJTWC) located at the U.S. Naval Western Oceanography Center, Pearl Harbor, Hawaii, assumes warning responsibilities. Assistance in determining satellite reconnaissance requirements, and in obtaining the resultant data, is provided by the PACAF Weather Support Unit, Hickam AFB, Hawaii.

Changes in this year's publication include: a new list of tropical cyclone names was implemented after Typhoon Wayne (25W); old Annex A now appears under the heading Tropical Cyclone Warning Statistics, Track and Fix Data; the Satellite Reconnaissance section was expanded to include technique development efforts and future developments; and the numbering of the sections was modified to make indexing the material easier.

Special thanks to: Lieutenant Colonel Daniel J. McMorrow for his significant contributions and support; the men and women of the 27th Communications Squadron, Operating Location Charlie and the Operations and Equipment Support departments of the Naval Oceanography Command Center, Guam for their continuing support by providing high quality real-time satellite imagery; Marine Corps Air Station, Futenma, Japan for sharing their satellite imagery of tropical cyclones; the Pacific Fleet Audio-Visual Center, Guam for their assistance in the reproduction of satellite data for this report; to the Navy Publications and Printing Service Branch Office, Guam; Dr. Bob Abbey and the Office of Naval Research for their technical support to this publication and support to the University of Hawaii for the Post Doctorate Fellow at JTWC; Dr. Mark Lander for his training efforts and suggestions; the Australian Meteorological Service for the coastal radar reports on tropical cyclones via the AFTN to JTWC; National Weather Service Pacific Region for their able assistance installing the AMOS equipment at Ujae and Enewetak, and AFTN hardware at JTWC; and the Republic of the Marshall Islands for endorsing the AMOS installations at Ujae and Enewetak; Mr John Brown and Mr. David Saltzberger of the Naval Oceanographic Office for their efforts regarding buoys and the Local User's Terminal data.

Note: Appendix A contains definitions, Appendix B names of tropical cyclones, Appendix C references and Appendix D information on how to obtain past issues of the Annual Tropical Cyclone Report (titled Annual Typhoon Report prior to 1980).

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INDIVIDUAL TROPICAL CYCLONES

CONTRACTIONS

AB	Air Base
ABIO	Significant Tropical Weather Advisory for the Indian Ocean
ABPW	Significant Tropical Weather Advisory for the Western Pacific Ocean
ACFT	Aircraft
ADP	Automated Data Processing
AFB	Air Force Base
AFGWC	Air Force Global Weather Central
AIREP	Aircraft (Weather) Report (Commercial and Military)
AMOS	Automatic Meteorological Observing Station
AOR	Area of Responsibility
APT	Automatic Picture Transmission
ARGOS	International Service for Drifting Buoys
ATCF	Automated Tropical Cyclone Forecast System
ATCM	Advanced Tropical Cyclone Model
AUTODIN	Automated Digital Network
AWDS	Automated Weather Distribution System
AWN	Automated Weather Network
BT LAT	Best Track Latitude
BT LON	Best Track Longitude
BT WN	Best Track Wind
CCWF	Combined Confidence Wieghted Forecast
CDO	Central Dense Overcast
CI	Cirriform Cloud or Cirrus (or) Current Intensity (Dvorak)
CINCPAC	Commander-in-Chief Pacific AF - Air Force, FLT - Navy
CLD	Cloud
CLIM	Climatology
CLIP or CLIPER	Climatology and Persistence Technique
CM	Centimeter(s)
CNOC	Commander Naval Oceanography Command
COSM or COSMOS	Cyclops Objective Steering Model Output Statistics
CPA	Closest Point of Approach
CPHC	Central Pacific Hurricane Center
CSC	Cloud System Center
CSUM	Colorado State University Model
CYCLOPS	Tropical Cyclone Steering Program (HATTRACK and MOHATT)
DDN	Defense Data Network
DEG	Degree(s)
DFS	Digital Facsimile System
DMSP	Defense Meteorological Satellite Program
DSAT	Digital Satellite Acquitition System
DSN	Defense Switched Network
DTG	Date Time Group
DWIPS	Digital Weather Image Processing System
FI	Forecast Intensity (Dvorak)
FNOC	Fleet Numerical Oceanography Center
FT	Feet
GMT	Greenwich Mean Time
GOES	Geostationary Operational Environmental Satellite
HATTRACK	Hurricane and Typhoon Tracking and Steering Program
HPAC	Mean of XTRP and CLIM Techniques (Half Persistence and Climatology)
HR	Hour(s)
ICAO	International Civil Aviation Organization
INIT	Initial
INST	Instruction
IR	Infrared
KM	Kilometer(s)
KT	Knot(s)
LAN	Local Area Network
LLCC	Low-Level Circulation Center
LUT	Local User's Terminal
LVL	Level
M	Meter(s)
MAX	Maximum
MB	Millibar(s)
MET	Meteorological
MIN	Minimum
MM	Millimeter(s)
MOHATT	Modified HATTRACK
MOVG	Moving
MSLP	Minimum Sea-level Pressure
NARDAC	Naval Regional Data Automation Center
NAS	Naval Air Station
NEDN	Naval Environmental Data Network

NEDS	Naval Environmental Display Station
NEPRF	Naval Environmental Prediction Research Facility
NESDIS	National Environmental Satellite, Data, and Information Service
NESN	Naval Environmental Satellite Network
NM	Nautical Mile(s)
NOAA	National Oceanic and Atmospheric Administration
NOARL	Naval Oceanographic and Atmospheric Research Laboratory
NOCC	Naval Oceanography Command Center
NODDES	Naval Environmental Data Network Oceanographic Data Distribution and Expansion System
NODDS	Navy/NOAA Oceanographic Data Distribution System
NOGAPS	Navy Operational Global Atmospheric Prediction System
NRPS or NORAPS	Navy Operational Regional Atmospheric Prediction System
NSDS	Naval Satellite Display System
NSDS-G	Naval Satellite Display System - Geostationary
NWOC	Naval Western Oceanography Center
NWS	National Weather Service
NR	Number
NRL	Naval Research Laboratory
OBS	Observations
ONR	Office of Naval Research
OTCM	One Way (Interactive) Tropical Cyclone Model
PACDIGS	Pacific Digital Information Graphics System
PACMEDS	Pacific Meteorological Data System
PACOM	Pacific Command
PCN	Position Code Number
PDN	Public Data Network
PIREP	Pilot Weather Report(s)
POS ER	(Initial) Position Error
RADOB	Radar Observation
RECON	Reconnaissance
RRDB	Reference Roster Data Base
RSDB	Raw Satellite Data Base
SAT	Satellite
SEC	Second
SDHS	Satellite Data Handling System
SFC	Surface
SGDB	Satellite Global Data Base
SLP	Sea-Level Pressure
SSM/I	Special Sensor Microwave/ Imager
SST	Sea Surface Temperature
STNRY	Stationary
ST	Subtropical
STR	Subtropical Ridge
STY	Super Typhoon
TAPT	Typhoon Acceleration Prediction Technique
TC	Tropical Cyclone
TCFA	Tropical Cyclone Formation Alert
TD	Tropical Depression
TDA	Typhoon Duty Assistant
TDO	Typhoon Duty Officer
TIROS	Television Infrared Observational Satellite
TOGA	Tropical Ocean Global Atmosphere
TS	Tropical Storm
TUTT	Tropical Upper-Tropospheric Trough
TY	Typhoon
TYAN	Typhoon Analog (Program)
TYMNET	Time-Sharing Network: Commercial wide area network connecting micro- and mainframe computers
ULAC	Upper-Level Anticyclone
ULCC	Upper-Level Circulation Center
USAF	United States Air Force
USN	United States Navy
VIS	Visual
WESTPAC	Western (North) Pacific
WMO	World Meteorological Organization
WRNG	Warning(s)
WW ER	Wind Warning Error
W#	Warning Number
XTRP	Extrapolation
Z	Zulu Time (Greenwich Mean Time)
24 ER	24-Hour (Position) Error
48 ER	48-Hour (Position) Error
72 ER	72-Hour (Position) Error
24 WE	24-Hour Wind (Warning) Error
48 WE	48-Hour Wind (Warning) Error
72 WE	72-Hour Wind (Warning) Error

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1. OPERATIONAL PROCEDURES

1.1 GENERAL

The Joint Typhoon Warning Center (JTWC) provides a variety of routine products and services to the organizations within its area of responsibility, including:

1.1.1 SIGNIFICANT TROPICAL WEATHER ADVISORIES — Issued daily, to describe all tropical disturbances and their potential for further development during the advisory period.

1.1.2 TROPICAL CYCLONE FORMATION ALERTS — Issued when synoptic or satellite data indicate the development of a tropical cyclone is likely within 24 hours in a specified area.

1.1.3 TROPICAL CYCLONE/ TROPICAL DEPRESSION WARNINGS — Issued periodically throughout each day to provide forecasts of position, intensity, and wind distribution for tropical cyclones in JTWC's area of responsibility (AOR).

1.1.4 PROGNOSTIC REASONING MESSAGES — Issued with each warning for tropical depressions, tropical storms, typhoons and super typhoons in the western North Pacific to discuss the rationale for JTWC's warnings.

1.1.5 PRODUCT CHANGES — The contents and availability of the above JTWC products are stipulated in USCINCPACINST 3140.1 (series). Changes to USCINCPACINST 3140.1T and JTWC products and services are proposed and discussed at the Annual Tropical Cyclone Conference. Significant changes this year to the warning system include: a new list of tropical cyclone names for the western North Pacific, Tropical Depression Warnings, inclusion of 30 kt wind radii at 48- and 72-hour forecast periods, and changing the message identifiers for the Prognostic Reasoning Messages and the Significant Tropical Weather Advisories.

1.2 DATA SOURCES

1.2.1 COMPUTER PRODUCTS — Numerical and statistical guidance are available from the USN Fleet Numerical Oceanography Center (FNOC) at Monterey, California. These products along with selected ones from the National Meteorological Center (NMC) are received through the Naval Environmental Data Network (NEDN), the Naval Environmental Satellite Network (NESN), and by micro-computer dial-up connections using military and commercial telephone lines. Numerical guidance is also received from Air Force Global Weather Center (AFGWC) at Omaha, Nebraska via the Pacific Digital Information Graphics System (PACDIGS), and from indigenous sources within our AOR.

1.2.2 CONVENTIONAL DATA — These data sets are comprised of land and shipboard surface observations, and enroute meteorological observations from commercial and military aircraft (AIREPS) recorded within six hours of synoptic times, and cloud-motion winds derived from satellite data . The conventional data is hand- and computer-plotted, and hand-analyzed in the tropics for the surface/gradient and 200 mb levels. These analyses are prepared twice daily from 0000Z and 1200Z synoptic data. Also, FNOC supplies JTWC with computer generated analyses and prognoses, from 0000Z and 1200Z synoptic data at the surface, 850 mb, 700 mb, 500 mb, 400 mb, 200 mb levels, and deep layer mean winds.

1.2.3 SATELLITE RECONNAISSANCE — Meteorological satellite imagery recorded at USAF/USN ground sites and USN ships supply day and night coverage in JTWC's area of responsibility. Interpretation of these satellite data provides tropical cyclone positions and estimates of current and forecast intensities (Dvorak, 1984). A USAF tactical satellite site

and Air Force Global Weather Central currently receive and analyze special sensor microwave/imager (SSM/I) data to provide estimates of 30-knot wind radii near tropical cyclones. Use of satellite reconnaissance is discussed further in section 2. Reconnaissance and Fixes.

1.2.4 RADAR RECONNAISSANCE — Land-based radar observations are used to position tropical cyclones. Once a well-defined tropical cyclone moves within the range of land-based radar sites, their reports are invaluable for determination of movement. Use of radar reports during 1989 is discussed in section 2. Reconnaissance and Fixes.

1.2.5 DRIFTING METEOROLOGICAL BUOYS — In 1989, no drifting meteorological buoys were specifically deployed in the western North Pacific for tropical cyclone warning support. Five of the nine buoys from the 1988 deployment and one from the 1987 deployment continued operations into 1989. Buoys provided data as Tropical Storm Winona (01W) and Typhoon Brenda (03W) crossed the Philippine Sea, but by late May the last buoy ceased operation. In 1989 Commander, Naval Oceanography Command put into action the NAVOCEANCOM Integrated Drifting Buoy Plan 1989-1994 to provide mini-drifter buoys to meet USCINCPACFLT requirements including tropical cyclone warning support.

JTWC acquires drifting buoy data directly through its Local User Terminal (LUT). The buoys transmit data to the TIROS-N polar orbiting satellites, which in turn relay the data to JTWC's LUT. Additionally, the data stored aboard the satellite are recovered via Service ARGOS and NOAA/NESDIS. NOAA/NESDIS processes and distributes the meteorological data to users via the National Meteorological Center (NMC) and the Automated Weather Network (AWN).

1.2.6 AUTOMATIC WEATHER OBSERVING STATIONS—Through a cooperative effort between Naval Oceanography Command and NOAA, the first of two HANDAR stations in the Mariana Islands was installed on Saipan in 1986. The second installation followed the next year on Rota. HANDAR data are received at JTWC through the Airfield Fixed Telecommunications Network (AFTN) and the AWN. Now, with the cooperation of NOAA, the Department of the Interior, and the Naval Oceanography Command, a network of 20 Automated Meteorological Observing Stations (AMOS) is planned to be completed throughout Micronesia by 1993. In 1988, the first AMOS site was installed at Faraulep Island (WMO 52005) in the central Carolines. In 1989, two more AMOS started operations at Ujae and Enewetak in the Marshall Islands. JTWC receives AMOS data from all sites via the AWN. In addition, data from the Faraulep site

Table 1-1. AUTOMATIC WEATHER OBSERVING STATIONS SUMMARY

Site	Location	Callsign	Type	System	Installed
Saipan	(15.2°N, 145.7°E)	15D151D2	HANDAR	ARC**	1986
Rota	(14.4°N, 145.2°E)	15D16448	HANDAR	ARC	1987
Faraulep	(8.6°N, 144.6°E)	FARP2/52005	AMOS	C-MAN/ARGOS*	1988
Ujae	(8.9°N, 165.8°E)	UJAP2	AMOS	C-MAN***	1989
Enewetak	(11.4°N, 162.3°E)	ENIP2	AMOS	C-MAN	1989

* System ARGOS data collection (via TIROS-N)
** Automated Remote Collection system (via GOES West)
*** Coastal-Marine Automated Network (via GOES West)

can be received real time via service ARGOS. Summary of current AMOS appears in Table 1.1.

1.3 COMMUNICATIONS

Primary communications support is provided by the Naval Telecommunications Center (NTCC), Nimitz Hill, a component of the Naval Communications Area Master Station, Western Pacific (NAVCAMS WESTPAC). JTWC uses the following communications systems:

1.3.1 AUTOMATED DIGITAL NETWORK (AUTODIN) — AUTODIN is used for dissemination of warnings, alerts and other related bulletins to DOD and other US Government installations. These messages are relayed for further transmission over Navy Fleet Broadcasts, and Coast Guard CW (continuous wave Morse Code) and voice broadcasts. AUTODIN messages can be relayed to commercial telecommunications for delivery to non-DOD users. Inbound message traffic for JTWC is received via AUTODIN addressed to NAVOCEANCOMCEN GQ//JTWC// or DET 1 1WW NIMITZ HILL GQ//CC//.

1.3.2 AUTOMATED WEATHER NETWORK (AWN) — The AWN provides weather data over the Pacific Meteorological Data System (PACMEDS). Operational at JTWC since April 1988, the PACMEDS allows Pacific-Theater agencies to receive weather information at 1200 baud. Early in 1989, JTWC also became the first Pacific unit to use the AWNCOM/WINDS software and a microcomputer to send and receive data via the PACMEDS. The system will eventually provide effective storage and manipulation of the large volume of meteorological reports available from throughout JTWC's vast AOR. Through the AWN, JTWC has limited access to data available on the Global Telecommunications System (GTS).

1.3.3 DEFENSE SWITCHED NETWORK (DSN) — DSN, formerly AUTOVON, is a world-wide general purpose switched telecommunications network for the Department of Defense. The network provides a rapid and vital voice link for JTWC to communicate tropical cyclone information to DOD installations. The DSN telephone numbers for JTWC are 344-4224 or 321-2345.

1.3.4 NAVAL ENVIRONMENTAL DATA NETWORK (NEDN) — The NEDN is the primary link to FNOC to obtain computer generated analyses and prognoses. It is also a backup communication line for requesting and receiving the objective tropical cyclone forecast aids from FNOC's mainframe computers. The NEDN allows JTWC to communicate directly to the other Naval Oceanography Command Centers around the world.

1.3.5 PUBLIC DATA NETWORK (PDN) — A commercial packet switching network that provides low-speed interactive transmission to users of FNOC products. The PDN is now the primary method for JTWC to request and receive FNOC produced objective tropical cyclone forecast aids. The PDN allows direct access of FNOC products via the Automated Tropical Cyclone Forecast (ATCF) system. The PDN also serves as an alternate method of obtaining FNOC analyses and forecast fields. TYMNET is the contractor providing PDN services to FNOC.

1.3.6 DEFENSE DATA NETWORK (DDN) —The DDN is a DOD computer communications network utilized to exchange data files. Because the DDN has links, or gateways, to non-military information networks, it is primarily used to exchange data with the research community.

1.3.7 TELEPHONE FACSIMILE (TELEFAX) — TELEFAX provides the capability to rapidly scan and transmit, or receive, documents over commercial telephone lines or DSN. TELEFAX is used to disseminate tropical cyclone advisories and warnings to key agencies on Guam and, in special situations, the other Micronesian Islands. Inbound documents

for JTWC are received via commercial telephone at (671) 477-6186. If inbound through DSN, the Guam DSN operator 322-1110 can transfer the call to the commercial number 477-6186.

1.3.8 NAVAL ENVIRONMENTAL SATELLITE NETWORK (NESN) — The NESN's primary function is to pass satellite data from the satellite global data base at FNOC to regional centers. Similarly, it can pass satellite data from NOCC/JTWC to FNOC or other regional centers. Also, it provides a limited back-up for the NEDN.

1.3.9 AIRFIELD FIXED TELECOMMUNICATIONS NETWORK (AFTN) — AFTN was installed at JTWC in January 1990. Though AFTN is primarily for the exchange of aviation information; weather information and warnings are also distributed via this network. AFTN also provides point-to-point communication with other warning agencies. JTWC's AFTN identifier is PGUMYMYT.

1.3.10 LOCAL USER'S TERMINAL (LUT) — JTWC uses a LUT, provided by the Naval Oceanographic Office, as the primary means of receiving real-time data from drifting meteorological buoys and some of the Micronesia AMOS via the polar orbiting NOAA satellites.

1.4 DATA DISPLAYS

Equipment maintenance is provided by the Equipment Support Department of the Naval Oceanography Command Center, Guam.

1.4.1 NAVAL ENVIRONMENTAL DISPLAY STATION (NEDS) — The NEDS receives, processes, stores, displays and prints copies of FNOC environmental products. It drives the fleet facsimile broadcast and can also be used to generate the requests for objective tropical cyclone forecast techniques.

1.4.2 AUTOMATED TROPICAL CYCLONE FORECAST SYSTEM (ATCF) — The ATCF has decreased message preparation time and reduced the number of corrections to JTWC's alerts and warnings. In 1989 for the first time, the ATCF automatically computed the myriad of statistics calculated by JTWC. Links were established through a Local Area Network (LAN) to the NOCC Operations watch team to facilitate the generation of Tropical Cyclone Warning graphics for the Fleet Facsimile Broadcasts and their local metwatch and warning products for Micronesia. A module permits satellite reconnaissance fixes to be input from Det 1, 1WW into the LAN. Several other modules are still under development including: direct links to NTCC, the LUT, and AWNCOM.

1.4.3 PACIFIC DIGITAL INFORMATION GRAPHICS SYSTEM (PACDIGS) — The PACDIGS is a communications circuit that was expanded to include JTWC in 1988. Air Force Global Weather Central (AFGWC) at Omaha, Nebraska provides a standard set of numerical products to the PACDIGS circuit which can be used for additional evaluation in the development of tropical cyclone warnings.

1.4.4 NAVAL SATELLITE DISPLAY SYSTEM (NSDS) — The NSDS functions as a display of FNOC stored Defense Meteorological Satellite Program (DMSP) imagery and low resolution geostationary imagery . It is the primary means for JTWC to observe the Indian Ocean.

1.4.5 NAVAL SATELLITE DISPLAY SYSTEM-GEOSTATIONARY(NSDS-G) — The NSDS-G is the primary system used to process high resolution geostationary imagery for tropical cyclone positioning and intensity estimates for the western Pacific Ocean. Its built-in sectorizer allows monitoring of numerous cyclones or suspect areas on a small enough scale to expand and evaluate the data effectively.

1.5 ANALYSES

The JTWC Typhoon Duty Officer (TDO) routinely does manual streamline analyses of composite surface/gradient-level (3000 ft (914 m)) and Upper-tropospheric (centered on the 200 mb level) data for 0000Z and 1200Z each day. Manual sea-level pressure analyses concentrating on the mid-latitudes are available from the NOCC Operations watch team. Computer analyses of the surface, 850, 700, 500, 400, and 200 mb levels, deep layer mean winds, and frontal boundaries are available from the 0000Z and 1200Z FNOC data bases. Additional sectional charts at intermediate synoptic times and auxiliary charts, such as station-time plot diagrams and pressure-change charts, are analyzed during periods of significant tropical cyclone activity.

1.6 FORECAST PROCEDURES

1.6.1 INITIAL POSITIONING — The warning position is the best estimate of the center of the surface circulation at synoptic time. It is estimated from an analysis of all fix information received from one hour before to one and one-half hours after synoptic time. The analysis is aided by a computer-generated objective best track scheme that weights fix information based on its statistical accuracy. The TDO includes synoptic observations and other information to adjust the position, testing consistency with the past direction, speed of movement and the influence of the different scales of motions. If the fix data are not available due to reconnaissance platform malfunction or communication problems, or are considered unrepresentative, synoptic data and/or extrapolation from previous fixes are used.

1.6.2 TRACK FORECASTING — A preliminary forecast track is developed based on an evaluation of the rationale behind the previous warning and the guidance given by the most recent set of objective techniques (see 5.2), numerical prognoses, recent movement, satellite animation, and other objective and empirical techniques. This preliminary track is then subjectively modified based on the following considerations:

1.6.2.1 The prospects for recurvature or erratic movement are evaluated. This determination is based primarily on the present and forecast positions and amplitudes of the middle-tropospheric, mid-latitude troughs and ridges as depicted on the latest upper-air analyses and numerical forecasts.

1.6.2.2 Determination of the best steering level is partly influenced by the maturity and vertical extent of the tropical cyclone. Shallow or sheared systems would be steered by the lower - tropospheric flow, whereas deep or mature cyclones would be affected by mid-level or deep-layer steering. For mature tropical cyclones located south of the subtropical ridge axis, forecast changes in speed of movement are closely correlated with anticipated changes in the intensity or relative position of the ridge. When steering currents are relatively weak, the tendency for tropical cyclones to move northward due to internal forces are considered. North of the subtropical ridge the polar westerlies and shortwaves greatly affect tropical cyclone steering and intensity.

1.6.2.3 Over the 12- to 72-hour (12- to 48-hour in the Southern Hemisphere) forecast period, speed of movement during the early forecast period is usually biased towards persistence, while the later forecast periods are biased towards objective techniques. When a tropical cyclone moves poleward, and toward the mid-latitude steering currents, speed of movement becomes increasingly more biased toward a selective group of objective techniques capable of estimating acceleration.

1.6.2.4 The proximity of the tropical cyclone to other tropical cyclones is closely evaluated to determine if there is a possibility of interaction. If the proximity is less than 900 nm (1665 km), binary interaction tracking techniques are considered.

A final check is made against climatology to determine if the forecast track is reasonable. If the forecast deviates greatly from one of the climatological tracks, the forecast rationale is reevaluated.

1.6.3 INTENSITY FORECASTING — Heavy reliance is placed on the empirically derived Dvorak (1984) technique for forecasting tropical cyclone intensity. Other techniques used for forecasting intensity are extrapolation of synoptic wind and pressure data and climatology. An evaluation of the entire synoptic situation is made, including the location of major troughs and ridges, the position and intensity of the Tropical Upper-Tropospheric Trough (TUTT), if present. The vertical and horizontal extent of the tropical cyclone's cyclonic circulation, and the extent of the associated upper-level outflow patterns are considered. Animated satellite data plays a key role in the evaluation of intensification potential. Each intensity forecast is affected by the accompanying forecast track and environmental influences along that track; such as, terrain, vertical wind shear and extratropical weather features. JTWC also incorporates a new interactive climatology scheme to help determine intensity forecasts.

1.6.4 WIND-RADII FORECASTING -- JTWC uses a wind profile and steering diagnostic developed by Major J. Martin and Dr. G. J. Holland (Office of Naval Research contractor). The technique adapts an earlier work (Holland, 1980) and specifically addresses the need for realistic 30-, 50- and 100-kt wind radii around tropical cyclones. It solves equations for basic gradient wind relations within the tropical cyclone area, using input parameters obtained from enhanced infrared satellite imagery. The diagnosis also addresses asymmetric areas of winds caused by tropical cyclone movement. Size and intensity parameters are used to diagnose internal steering components of tropical cyclone motion known collectively as "beta-drift".

1.6.5 EXTRATROPICAL TRANSITION — When a tropical cyclone is forecast to become an extratropical system, JTWC coordinates the transfer of warning responsibility with the appropriate Naval Oceanography Command Regional Center, which assumes warning responsibilities for the extratropical system.

1.6.6 TRANSFER OF WARNING RESPONSIBILITIES — JTWC coordinates the transfer of tropical warning responsibility for tropical cyclones entering or exiting its AOR. For tropical cyclones crossing the dateline in the North Pacific Ocean, JTWC coordinates with the Central Pacific Hurricane Center (CPHC), Honolulu via the Naval Western Oceanography Center (NWOC), Pearl Harbor. For the South Pacific Ocean, JTWC coordinates with NWOC.

In the event JTWC should become incapacitated, the Alternate Joint Typhoon Warning Center (AJTWC), co-located with NWOC, assumes JTWC's functions.

1.7 WARNINGS

JTWC issues two types of warnings: Tropical Cyclone Warnings and Tropical Depression Warnings.

Tropical Cyclone Warnings are issued when a closed circulation is evident and maximum sustained winds are forecast to reach 34 kt (18 m/sec) within 48 hours, or when the tropical cyclone is in such a position that life or property may be endangered within 72 hours.

Each Tropical Cyclone Warning is numbered sequentially and includes the following information: the current position of the surface center; estimate of the position accuracy and the supporting reconnaissance (fix) platforms; the direction and speed of movement during the past six hours (past 12 hours in the Southern Hemisphere); and the intensity and radial extent of over 30-, 50-, and 100-kt surface winds, when applicable. At

forecast intervals of 12, 24, 48, and 72 hours (12, 24, and 48 hours in the Southern Hemisphere), information on the tropical cyclone's anticipated position, intensity and wind radii is provided. In addition, vectors indicating the mean direction and mean speed between forecast positions are included in all warnings.

Warnings in the western North Pacific and North Indian Oceans are issued every six hours valid at standard times: 0000Z, 0600Z, 1200Z and 1800Z (every 12 hours: 0000Z, 1200Z or 0600Z, 1800Z in the Southern Hemisphere). All warnings are released to the communications network no earlier than synoptic time and no later than synoptic time plus two and one-half hours, so that recipients are assured of having all warnings in hand by synoptic time plus three hours (0300Z, 0900Z, 1500Z and 2100Z).

Tropical Depression Warnings are issued only for western North Pacific tropical depressions that are not expected to reach the criteria for Tropical Cyclone Warnings, as mentioned above. The depression warning contains the same information as a Tropical Cyclone Warning except the Tropical Depression Warning is issued every 12 hours at standard synoptic times and extends only to the 36-hour forecast period.

Both Tropical Cyclone and Tropical Depression Warning forecast positions are later verified against the corresponding best track positions (obtained during detailed post-storm analyses) to determine the most probable path and intensity of the cyclone. A summary of the verification results for 1989 is presented in section 5. Summary of Forecast Verification.

1.8 PROGNOSTIC REASONING MESSAGES

These plain language messages provide meteorologists with the rationale for the forecasts for tropical cyclones in the western North Pacific Ocean. It also discusses alternate forecast scenarios. Prognostic reasoning messages are prepared to complement each warning. In addition to this message, prognostic reasoning information is provided in the remarks section of warnings when significant forecast changes are made or when deemed appropriate by the TDO.

1.9 TROPICAL CYCLONE FORMATION ALERTS

Tropical Cyclone Formation Alerts are issued whenever interpretation of satellite imagery and other meteorological data indicates that the formation of a significant tropical cyclone is likely. These alerts will specify a valid period not to exceed 24 hours and must either be canceled, reissued, or superseded by a warning prior to expiration.

1.10 SIGNIFICANT TROPICAL WEATHER ADVISORIES

This product contains a description of all tropical disturbances in JTWC's area of responsibility (AOR) and their potential for further (tropical cyclone) development. In addition, all tropical cyclones in warning status are briefly discussed.

Two separate messages are issued daily and each is valid for a 24-hour period. The Significant Tropical Weather Advisory for the Western Pacific Ocean (ABPW10 PGTW) covers the area east of 100° east longitude to the dateline and is issued by 0600Z. The Significant Tropical Weather Advisory for the Indian Ocean (ABIO10 PGTW) covers the area west of 100° east longitude to the coast of Africa and is issued by 1800Z. These are reissued whenever the situation warrants. For each suspect area, the words "poor", "fair", or "good" are used to describe the potential for development. "Poor" will be used to describe a tropical disturbance in which the meteorological conditions are currently unfavorable for development. "Fair" will be used to describe a tropical disturbance in which the meteorological conditions are favorable for development, but significant development has not commenced.

"Good" will be used to describe the potential for development of a disturbance covered by an alert.

2. RECONNAISSANCE AND FIXES

2.1 GENERAL

The Joint Typhoon Warning Center depends on reconnaissance to provide necessary, accurate, and timely meteorological information in support of advisories, alerts and warnings. JTWC relies primarily on two reconnaissance platforms: satellite and radar. In data rich areas, synoptic data are also used to supplement the above. As in past years, the optimum use of all available reconnaissance resources to support JTWC's products remains a primary concern. The weighing of the specific capabilities and limitations of each reconnaissance platform, and the tropical cyclone's threat to life and property both afloat and ashore, continue to be an important part of careful product preparation.

2.2 RECONNAISSANCE AVAILABILITY

2.2.1 SATELLITE — Fixes from Air Force/Navy ground sites and Navy ships provide day and night coverage in JTWC's area of responsibility. Interpretation of this satellite imagery yields tropical cyclone positions and estimates of current and forecast intensities through the Dvorak technique. A new capability provided by the Special Sensor Microwave/Imager (SSM/I) data is used to determine the extent of the 30-kt winds around the tropical cyclone and to aid in tropical cyclone positioning.

2.2.2 RADAR — Land-based radar remotely senses and maps precipitation within tropical cyclones in the proximity (usually within 175 nm (325 km) of radar sites in the Republic of the Philippines, Taiwan, Hong Kong, Japan, South Korea, Kwajalein and Guam. The next radar upgrade will be the arrival of the next generation Doppler radars in the early 1990's.

2.2.3 SYNOPTIC — JTWC also determines tropical cyclone positions based on the analysis of the surface/gradient-level synoptic data. These positions are an important supplement to fixes provided by remote sensing platforms and become invaluable in situations where neither satellite nor radar fixes are available.

2.3 SATELLITE RECONNAISSANCE SUMMARY

The Air Force provides satellite reconnaissance support to JTWC through the DMSP Tropical Cyclone Reporting Network (DMSP Network), which consists of tactical sites and a centralized facility. Tactical DMSP sites monitoring DMSP, NOAA and geostationary satellite data are located at Nimitz Hill, Guam; Clark AB, Republic of the Philippines; Kadena AB, Okinawa, Japan; Osan AB, Republic of Korea; and Hickam AFB, Hawaii. These sites provide a combined coverage that includes most of JTWC's area of responsibility in the western North Pacific, from near the date line westward to the Malay Peninsula. For the remainder of its AOR, JTWC relies on the AFGWC to provide coverage using stored satellite data. The Naval Oceanography Command Detachment, Diego Garcia, furnishes interpretation of NOAA polar orbiting coverage in the central Indian Ocean and USN ships equipped for direct satellite readout contribute supplementary support. Additionally, civilian contractors with the U.S. Army at Kwajalein Atoll provide satellite and radar information on tropical cyclones that develop in the Marshall Islands to supplement Det 1, 1WW's satellite coverage. An additional source of satellite data is DMSP satellite mosaics available from the Fleet Numerical Oceanography Center via the NEDN and NESN lines. This valuable data is used to metwatch the areas not in the DMSP tactical site satellite coverage and provides forecasters the capability to monitor tropical cyclones that AFGWC satellite analysts are fixing.

In addition to polar orbiter imagery, Det 1, 1 WW uses geostationary imagery to support the reconnaissance mission. Low resolution imagery is received through animation loopers at the DMSP tactical sites. The animation of these images is invaluable in depicting systems in their formative stages and determining coarse motion vectors. Animation is also valuable in assessing environmental changes affecting tropical cyclone behavior. In addition to this capability, Det 1, 1WW is able to receive high resolution digital geostationary data through the Naval Satellite Dissemination System-Geostationary (NSDS-G) which is the primary source of geostationary data used for positioning and intensity analyses.

AFGWC is the centralized member of the DMSP network. In support of JTWC, AFGWC processes stored imagery from DMSP and NOAA spacecraft. Stored imagery is recorded onboard the spacecraft as they pass over the earth and is later down-linked to AFGWC via a network of command readout sites and communication satellites. This enables AFGWC to obtain the coverage necessary to fix all tropical cyclones within JTWC's AOR. AFGWC has the primary responsibility to provide tropical cyclone reconnaissance over the entire Indian Ocean, southwest Pacific, and the area near the dateline in the western North Pacific Ocean. Additionally, AFGWC can be tasked to provide tropical cyclone support in the western North Pacific as backup to coverage routinely available in that region.

The hub of the DMSP network is Det 1, 1WW, colocated with JTWC at Nimitz Hill, Guam. Based on available satellite coverage, Det 1, 1WW is responsible for coordinating satellite reconnaissance requirements with JTWC and tasking the individual network sites for the necessary tropical cyclone fixes, current intensity estimates and forecast intensities. When a particular satellite pass is selected to support the development of JTWC's next tropical cyclone warning, two sites are tasked to fix the tropical cyclone from the same pass. This "dual-site" concept provides the necessary redundancy that virtually guarantees JTWC a satellite fix to support each warning.

The network provides JTWC with several products and services. The main service is one of monitoring the AOR for indications of tropical cyclone development. If development is detected, JTWC is notified. Once JTWC issues either a Tropical Cyclone Formation Alert or warning, the network provides three products: tropical cyclone positions, current intensity estimates and forecast intensities. Each satellite tropical cyclone position is assigned a Position Code Number (PCN), which is a measure of positioning confidence. The PCN is determined by the combination of availability of visible landmarks in the image that can be used as references for precise gridding and the degree of organization of the tropical cyclone's cloud system (Table 2-1).

Det 1, 1 WW provides two estimates of the tropical cyclone's current intensity per day once JTWC is in alert status and four estimates when in warning status. Current intensity estimates and 24-hour intensity forecasts are made using the Dvorak technique (NOAA Technical Report NESDIS 11) for both visual and enhanced infrared imagery (Figure 2-1). The enhanced infrared technique is preferred due to its increased objectivity and accuracy, however, the visual technique is used to supplement this information during the daylight hours. For subtropical cyclones, intensity estimates are made using the Hebert and Poteat technique (NOAA Technical Memorandum NWS SR-83, 1975).

TABLE 2-1 **POSITION CODE NUMBERS (PCN)**

PCN	METHOD FOR CENTER DETERMINATION/GRIDDING
1	EYE/GEOGRAPHY
2	EYE/EPHEMERIS
3	WELL DEFINED CIRCULATION CENTER/GEOGRAPHY
4	WELL DEFINED CIRCULATION CENTER/EPHEMERIS
5	POORLY DEFINED CIRCULATION CENTER/GEOGRAPHY
6	POORLY DEFINED CIRCULATION CENTER/EPHEMERIS

2.3.1 SATELLLITE PLATFORM SUMMARY Figure 2-2 shows the status of operational polar orbiting spacecraft. Two DMSP spacecraft were operational during 1989. Spacecraft 19543 (F8), which carries the Special Sensor Microwave/Imager (SSM/I), was operational throughout the year. Spacecraft 20542 (F9) was operational throughout the year, despite some thermal channel degradation problems which were corrected in early 1989. The NOAA 10 and NOAA 11 spacecraft performed well throughout the year.

2.3.2 STATISTICAL SUMMARY — During 1989, the DMSP network was the primary input to JTWC for operational warnings and post analysis best tracks in the entire 53 million square mile area of responsibility for the warning center. Almost all the warnings were based on satellite reconnaissance. JTWC received a total of 3133 satellite fixes from the DMSP network on 35 tropical cyclones in the western North Pacific Ocean. Of this, 49 percent were from polar orbiters, while 51 percent were from geostationary. With the increased emphasis this year on the early detection of tropical depressions, the DMSP network began fixing storms earlier in their lifecycle and continued fixing them until they weakened below 25 kt or became extratropical. This emphasis contributed significantly to the 50 percent increase in the total number of fixes this year as compared to 1988. In addition, 124 fixes were made on tropical cyclones in the North Indian Ocean and 1625 on cyclones in the Southern Hemisphere. A comparison of those fixes with their corresponding best track positions is shown in Tables 2-2A and 2-2B. For the western North Pacific, the total mean error was comparable to the multi-year average and has essentially remained constant. In addition to the mean errors verses JTWC best track, Figure 2-3 depicts the 90th percentile values, i.e. 90 percent of the fixes fall within these limits, stratified by current intensity. This figure shows that errors decrease as a system becomes more intense. The greatest errors are found in the formative stages, with maximum sustained winds less than 25 kt. In general,

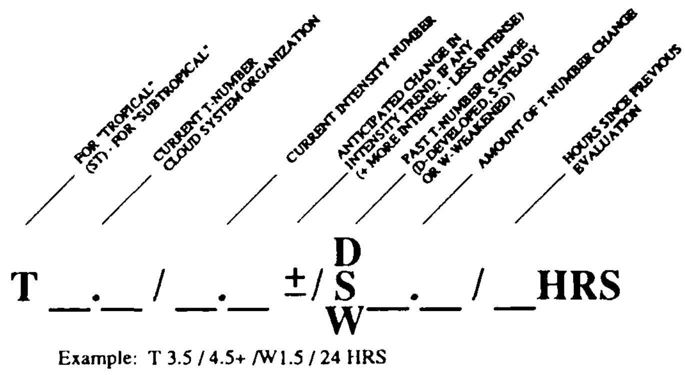


Figure 2-1. Dvorak code for communicating estimates of current and forecast intensity derived from satellite data. In the example, the current "T-number" is 3.5, but the current intensity is 4.5. The cloud system has weakened by 1.5 "T-numbers" since the previous evaluation conducted 24-hours earlier. The plus (+) symbol indicates an expected reversal of the weakening trend or very little further weakening of the tropical cyclone during the next 24-hour period.

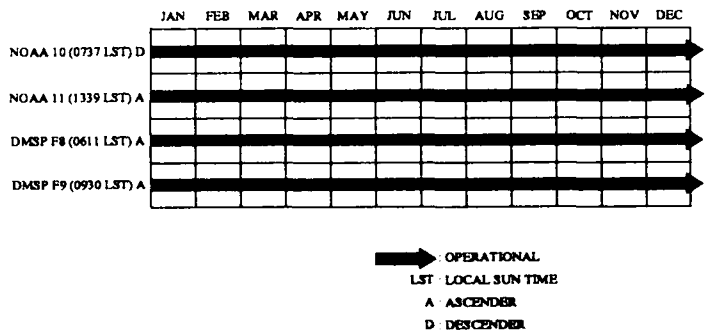


Figure 2-2. Polar orbitters for 1989.

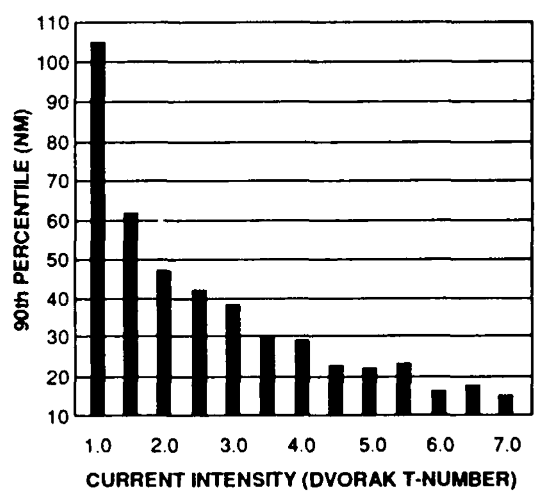


Figure 2-3. A stratification of western North Pacific satellite fix errors (90th percentile) and current intensities (Dvorak T-numbers). For example: for a tropical cyclone with a current intensity of T1.0, 90% of the fixes fell within 105 nm (195 km) of the final best track position.

TABLE 2-2A **MEAN DEVIATION (NM) OF ALL SATELLITE DERIVED TROPICAL CYCLONE POSITIONS FROM JTWC BEST TRACK POSITIONS IN THE WESTERN NORTH PACIFIC AND NORTH INDIAN OCEANS (NUMBER OF CASES IN PARENTHESES)**

	WESTERN NORTH PACIFIC OCEAN		NORTH INDIAN OCEAN	
PCN	1979-1988 AVERAGE	1989 AVERAGE	1980-1988 AVERAGE	1989 AVERAGE
1	14.0 (1698)	11.4 (150)	16.5 (44)	10.7 (20)
2	14.9 (3070)	11.8 (583)	15.2 (13)	12.0 (20)
3	21.0 (2275)	19.2 (140)	24.7 (42)	17.4 (5)
4	21.7 (2441)	19.6 (550)	41.3 (26)	18.4 (13)
5	36.8 (3932)	26.4 (209)	38.2 (343)	28.9 (32)
6	36.1 (6120)	31.7 (1467)	40.3 (481)	31.1 (15)
1&2	14.6 (4768)	11.7 (733)	16.2 (57)	11.3 (40)
3&4	21.3 (4716)	19.6 (690)	31.1 (68)	18.1 (18)
5&6	36.4 (10052)	31.1 (1676)	39.4 (824)	29.6 (47)
1,3&5	27.4 (7905)	19.9 (499)	34.7 (429)	21.5 (57)
2,4&6	27.4 (11631)	24.7 (2600)	39.7 (520)	19.7 (48)
TOTALS:	27.4 (19536)	23.9 (3099)	37.4 (949)	20.7 (105)

TABLE 2-2B **MEAN DEVIATION (NM) OF ALL SATELLITE DERIVED TROPICAL CYCLONE POSITIONS FROM JTWC BEST TRACK POSITIONS IN THE WESTERN SOUTH PACIFIC AND SOUTH INDIAN OCEANS (NUMBER OF CASES IN PARENTHESES)**

PCN	1985 - 1988 AVERAGE	1989 AVERAGE
1	16.3 (103)	15.3 (108)
2	16.5 (564)	15.3 (240)
3	34.8 (125)	20.3 (45)
4	27.0 (538)	23.7 (93)
5	40.6 (548)	30.9 (210)
6	37.1 (3651)	33.7 (735)
1 & 2	16.5 (667)	15.3 (348)
3 & 4	28.5 (663)	22.6 (138)
5 & 6	37.6 (4199)	33.1 (945)
1, 3 & 5	36.4 (776)	24.9 (363)
2, 4 & 6	33.5 (4753)	28.7 (1068)
TOTALS:	33.9 (5529)	27.7 (1431)

TABLE 2-3

MAXIMUM SUSTAINED WIND SPEED (KT) AS A FUNCTION OF DVORAK CURRENT AND FORECAST INTENSITY NUMBER AND MINIMUM SEA-LEVEL PRESSURE (MSLP)

TROPICAL CYCLONE INTENSITY NUMBER	WIND SPEED	MSLP (NW PACIFIC)
0.0	<25	----
0.5	25	----
1.0	25	----
1.5	25	----
2.0	30	1000
2.5	35	997
3.0	45	991
3.5	55	984
4.0	65	976
4.5	77	966
5.0	90	954
5.5	102	941
6.0	115	927
6.5	127	914
7.0	140	898
7.5	155	879
8.0	170	858

errors become smaller with increasing intensity. The network also provided an additional 345 fixes on tropical disturbances which did not develop into significant tropical cyclones. The standard relationship between tropical cyclone "T-number", maximum sustained surface wind speed (Dvorak, 1984) and minimum sea-level pressure (Atkinson and Holliday, 1977) for the Pacific is shown in Table 2-3.

2.3.3 NEW TECHNIQUES — In the past, one of the biggest challenges in providing satellite reconnaissance to JTWC has been in detecting and tracking low-level circulation centers and low level clouds lines at night. When available, the satellite analyst used the low light visual capability of the DMSP spacecraft. However, during 1989, DMSP network satellite forecasters developed an infrared enhancement for the NOAA spacecraft 3.7 micrometer channel which significantly improves the capability to identify and track exposed or partially exposed low-level circulations and low level cloud lines through the nighttime hours when mid or high cloud do not obscure the low clouds. This enhancement also accentuates the land-sea contrast, highlighting geography which can be used for more precise gridding. This enhancement is now routinely applied to images of tropical cyclones where shearing is either suspected or in progress.

As was mentioned earlier, the SSM/I, mounted on the F8 DMSP spacecraft, was operational most of 1989. Through the majority of the 1989 season, SSM/I technique development support was provided exclusively by analysts in the AFGWC Tropical Section. This support included bulletins describing the extent of 30-kt winds surrounding the tropical cyclone for all systems with maximum sustained winds of 50 kt or greater. Winds can only be obtained in rain-free areas and areas free of deep moisture. If the cloud system center was rain free, analysts provided center/eye positions based on the 85 gigahertz (GHz) microwave channel display. These positions provided a comparison with those made using visual and infrared spectral windows. Multispectral imaging, particularly with the 85 GHz channel which is able to "see through" the cirrus canopy, offers a rich area for development. In October 1989, Det 1, 1 WW obtained a prototype capability to ingest,

TABLE 2-4A

1989 NORTHERN HEMISPHERE
FIX PLATFORM SUMMARY

WESTERN NORTH PACIFIC		SATELLITE	RADAR	SYNOPTIC	TOTAL
TS WINONA	(01W)	78	11	1	90
STY ANDY	(02W)	129	50	0	180*
TY BRENDA	(03W)	96	24	0	120
TY CECIL	(04W)	53	6	0	59
TY DOT	(05W)	116	17	0	133
TS ELLIS	(06W)	39	2	1	42
TS FAYE	(07W)	102	9	1	111
STY GORDON	(08W)	160	24	0	184
TS HOPE	(09W)	109	69	0	178
TS IRVING	(10W)	48	16	0	64
TY JUDY	(11W)	132	93	0	225
TD 12W	(12W)	23	6	0	29
TS KEN-LOLA	(13W-14W)	94	112	4	210
TY MAC	(15W)	123	61	1	185
TY OWEN	(16W)	104	1	7	112
TY NANCY	(17W)	65	0	0	65
TS PEGGY	(18W)	37	0	0	37
TD 19W	(19W)	43	9	2	54
TS ROGER	(20W)	61	98	2	161
TD 21W	(21W)	37	0	1	38
TY SARAH	(22W)	140	73	0	213
TS TIP	(23W)	60	0	0	60
TS VERA	(24W)	70	62	0	132
TY WAYNE	(25W)	54	160	0	214
STY ANGELA	(26W)	182	31	0	213
TY BRIAN	(27W)	57	6	0	63
TY COLLEEN	(28W)	108	0	0	108
TY DAN	(29W)	81	21	1	103
STY ELSIE	(30W)	153	15	0	168
TY FORREST	(31W)	141	7	0	148
TY GAY	(32W)	38	14	0	52
TY HUNT	(33W)	127	18	3	148
TY IRMA	(34W)	146	0	0	146
TD 35W	(35W)	30	0	3	33
TY JACK	(36W)	97	63	0	160
TOTALS NWP:		3133	1068	27	4238*
PERCENTAGE OF TOTAL:		73.9%	25.4%	0.7%	100%

NORTH INDIAN OCEAN		SATELLITE	RADAR	SYNOPTIC	TOTAL
TC 01B	(01B)	27	0	0	27
TC 02A	(02A)	24	0	0	24
TC 32W	(32W)	73	0	0	73
TOTALS NIO:		124	0	0	124
PERCENTAGE OF TOTAL:		100%	0%	0%	100%

* ONE AIRBORNE RADAR FIX WAS RECEIVED

TABLE 2-4B		**1989 SOUTH PACIFIC AND SOUTH INDIAN OCEANS FIX PLATFORM SUMMARY**			
TROPICAL CYCLONES		SATELLITE	SYNOPTIC	RADAR	TOTAL
TC 01S	ADELININA	35	0	0	35
TC 02S	BARISAONA	125	0	0	125
TC 03S	ILONA	55	0	5	60
TC 04P	DILILAH	42	0	0	42
TC 05P	GINA	20	0	0	20
TC 06S	- - - -	34	0	0	34
TC 07S	EDME	37	0	0	37
TC 08S	FIRINGA	61	0	0	61
TC 09S	KIRRILY	68	0	0	68
TC 10P	HARRY	156	0	0	156
TC 11S	HANITRA	91	0	0	91
TC 12S	GIZELA	32	0	0	32
TC 13P	IVY	85	0	0	85
TC 14P	- - - -	21	0	0	21
TC 15P	JUDY	29	0	0	29
TC 16S	- - - -	16	0	0	16
TC 17S	MARCIA	23	0	0	23
TC 18S	- - - -	14	0	0	14
TC 19S	JINABO	66	0	0	66
TC 20S	NED	88	0	0	88
TC 21S	KRISSY	80	0	0	80
TC 22P	KERRY	26	0	0	26
TC 23P	AIVU	57	0	0	57
TC 24S	LEZISSY	22	0	0	22
TC 25P	LILI	68	0	0	68
TC 26S	ORSON	91	0	0	91
TC 27P	MEENA	112	0	0	112
TC 28P	ERNIE	71	0	0	71
TOTAL NUMBER OF FIXES:		1625	0	5	1630

process and display the SSM/I data realtime. Current plans are for the prototype system to be upgraded with improved hardware and software. Installation of these new systems is projected for Det 1, 1 WW and for DMSP sites at Clark AB, Kadena AB and Hickam AFB during the summer of 1990.

2.3.4 FUTURE OF SATELLITE RECONNAISSANCE — The future of satellite reconnaissance provides many unique challenges. As the SSM/I imagery becomes available throughout the DMSP network, training must be accomplished quickly to maximize the benefit. At this time, the majority of the emphasis has been placed on the 85 GHz and surface wind information. However, a great deal of unrealized information may lie in the other channels. Several Air Force investigators are examining this potential.

Det 1, 1 WW expects to receive an automated satellite imagery processing and display system designed specifically for the tropical cyclone reconnaissance mission during the 1991-1992 timeframe. The system will process and display polar orbiter and geostationary satellite data. It will have a broad spectrum of satellite data manipulation applications which will significantly enhance Det 1, 1WW support to the reconnaissance mission. In the meantime, Det 1, 1WW is developing its capabilities using a MacIntosh IIx™ computer system which has been programmed to ingest and display polar orbiter and geostationary satellite data.

In addition to SSM/I, the Mark III and Mark IV DMSP ground systems located at the Pacific DMSP sites should be upgraded with the Mark IVB state-of-the-art satellite imagery

ingest and display system during the 1992-93 timeframe. The near future of satellite reconnaissance is becoming more and more dependent on this upgrade, as the current systems become more difficult to support.

2.4 RADAR RECONNAISSANCE SUMMARY

Twenty-eight of the thirty-five significant tropical cyclones in the western North Pacific during 1989 passed within range of land-based radar with sufficient cloud pattern organization to be fixed. The land-based radar fixes that were obtained and transmitted to JTWC totaled 1068 for the Northern Hemisphere and 5 for the Southern Hemisphere. One radar fix was obtained by an aircraft of opportunity.

The WMO radar code defines three categories of accuracy: good (within 10 km (5 nm)), fair (within 10-30 km (5-16 nm)), and poor (within 30-50 km (16-27 nm)). Of the 1073 radar fixes encoded in this manner; 314 were good, 341 were fair, and 418 were poor. Compared to JTWC's best track, the mean vector deviation for land-based radar sites was 20 nm (37 km). Excellent support from the radar network through timely and accurate radar fix positioning allowed JTWC to track and forecast tropical cyclone movement through even the most difficult erratic tracks.

Five radar reports were received on Southern Hemisphere tropical cyclones; however, as in previous years, no radar reports were received on North Indian Ocean tropical cyclones.

2.5 TROPICAL CYCLONE FIX DATA

A total of 4238 fixes on thirty-five western North Pacific tropical cyclones and 124 fixes on three North Indian Ocean tropical cyclones were received at JTWC. Table 2-4A delineates the number of fixes per platform for each individual tropical cyclone for the western North Pacific and North Indian Oceans. Season totals and percentages are also indicated. Table 2-4B provides similar information for the South Pacific and South Indian Oceans.

3. SUMMARY OF WESTERN NORTH PACIFIC AND NORTH INDIAN OCEAN TROPICAL CYCLONES

3.1 GENERAL

The calendar year 1989 was a very busy year. JTWC issued warnings on a total of 35 tropical depressions, tropical storms and typhoons in the western North Pacific — 5 super typhoons, 16 less intense typhoons, 10 tropical storms and 4 tropical depressions — the most tropical cyclones since 1974 and the most typhoons since 1972. An extensive post analysis indicated that dissipating Ken (13W) and developing Lola (14W) merged into a single system, thus the total of 36 numbered cyclones was revised to 35 (Table 3-1). In any case, this is more than the climatological mean of 31 tropical cyclones in the western North Pacific (Table 3-2). The North Indian Ocean was fairly inactive with only 3 tropical cyclones occurring there — below the 5 per year average. During 1989, warnings were issued on a total of 37* Northern Hemisphere tropical cyclones. A chronology of western North Pacific and North Indian Ocean tropical cyclones is provided in Figure 3-1.

For the year, JTWC was in warning status 154 days compared to 114 in 1988. Again, considering only the western North Pacific, there were 46 days when the Center issued warnings on two cyclones and 9 days when it warned on three cyclones (Table 3-3). When the North Indian Ocean is included, there were a total of 167 days with warnings on one cyclone, 49 days with warnings on two cyclones, and 9 days with warnings on three. There were no days when warnings were issued on four or five tropical cyclones at once. Thus, JTWC was in Northern Hemisphere warning status 40% of the year; it was warning on two or more tropical cyclones during 58 days or 16% of the year.

JTWC issued 710 warnings on 35 western North Pacific tropical cyclones, 147 more than in 1987 and 239 more than last year. In addition, the Center put out 44 warnings on North Indian Ocean tropical cyclones, for a grand total of 754 Northern Hemisphere warnings. There were 51 initial Tropical Cyclone Formation Alerts issued on western North Pacific tropical disturbances (Table 3-4) and 8 on disturbances in the North Indian Ocean. Three out of the 35 significant tropical cyclones that developed in the western North Pacific did so without Formation Alerts. Alerts were issued on all tropical cyclones that formed in the North Indian Ocean. Tropical Cyclone 32W (Gay) was already in warning status when it entered the Bay of Bengal from the Gulf of Thailand.

* TC-32W (Gay) counted only once.

TABLE 3-1

WESTERN NORTH PACIFIC
SIGNIFICANT TROPICAL CYCLONES
FOR 1989

TROPICAL CYCLONE		PERIOD OF WARNING	NUMBER OF WARNINGS ISSUED	MAXIMUM SURFACE WINDS KT (M/SEC)	ESTIMATED MSLP (MB)
(01W)	TS WINONA	18 JAN - 19 JAN	5	55 (28)	984
(01W)	TS WINONA*	20 JAN - 21 JAN	8	30 (15)	1000
(02W)	STY ANDY	17 APR - 24 APR	26	140 (72)	898
(03W)	TY BRENDA	15 MAY - 20 MAY	20	75 (39)	967
(04W)	TY CECIL	22 MAY - 24 MAY	9	75 (39)	967
(05W)	TY DOT	05 JUN - 11 JUN	25	100 (51)	944
(06W)	TS ELLIS	20 JUN - 20 JUN	2	25 (13)	1002
(06W)	TS ELLIS*	22 JUN - 23 JUN	4	35 (18)	997
(07W)	TS FAYE	06 JUL - 11 JUL	21	55 (28)	980
(08W)	STY GORDON	11 JUL - 18 JUL	30	135 (69)	898†
(09W)	TS HOPE	16 JUL - 21 JUL	21	55 (28)	984
(10W)	TS IRVING	21 JUL - 24 JUL	14	55 (28)	984
(11W)	TY JUDY	22 JUL - 29 JUL	28	95 (49)	949
(12W)	TD 12W	29 JUL - 30 JUL	3	30 (15)	1000
(13W-14W)	TS KEN-LOLA	30 JUL - 04 AUG	23	50 (26)	982†
(15W)	TY MAC	01 AUG - 07 AUG	28	80 (41)	963
(16W)	TY OWEN	11 AUG - 18 AUG	28	75 (39)	967
(17W)	TY NANCY	11 AUG - 16 AUG	22	75 (39)	967
(18W)	TS PEGGY	16 AUG - 18 AUG	9	35 (18)	997
(19W)	TD 19W	17 AUG - 19 AUG	6	30 (15)	1000
(20W)	TS ROGER	24 AUG - 28 AUG	14	50 (26)	983†
(21W)	TD 21W	25 AUG - 28 AUG	7	30 (15)	1000
(22W)	TY SARAH	06 SEP - 14 SEP	33	125 (64)	916
(23W)	TS TIP	09 SEP - 13 SEP	20	50 (26)	987
(24W)	TS VERA	12 SEP - 16 SEP	16	50 (26)	987
(25W)	TY WAYNE	17 SEP - 20 SEP	12	65 (33)	976
(26W)	STY ANGELA	29 SEP - 10 OCT	46	130 (67)	910
(27W)	TY BRIAN	30 SEP - 03 OCT	13	80 (41)	963
(28W)	TY COLLEEN	01 OCT - 08 OCT	27	80 (41)	963
(29W)	TY DAN	08 OCT - 13 OCT	21	70 (36)	972
(30W)	STY ELSIE	14 OCT - 22 OCT	34**	140 (72)	898
(31W)	TY FORREST	22 OCT - 29 OCT	30	95 (49)	949
(32W)	TY GAY	02 NOV - 04 NOV	9***	100 (51)	943
(33W)	TY HUNT	16 NOV - 23 NOV	27	90 (46)	954
(34W)	STY IRMA	21 NOV - 22 NOV	3	25 (13)	1002
(34W)	STY IRMA*	25 NOV - 04 DEC	36	140 (72)	898
(35W)	TD 35W	07 DEC - 09 DEC	9	30 (15)	1000
(36W)	TY JACK	20 DEC - 28 DEC	21	125 (64)	916
		TOTAL:	710		

* REGENERATED
** FOUR ISSUED BY AJTWC.
*** WARNINGS IN WESTPAC BASIN. SEE TABLE 3-5 FOR WARNINGS IN INDIAN OCEAN.
† BASED ON SYNOPTIC DATA.

The criteria used in Table 3-2 are as follows:

1. If a tropical cyclone was first warned on during the last two days of a particular month and continued into the next month for longer than two days, then that system was attributed to the second month.

2. If a tropical cyclone was warned on prior to the last two days of a month, it was attributed to the first month, regardless of how long the system lasted.

3. If a tropical cyclone began on the last day of the month and ended on the first day of the next month, that system was attributed to the first month. However, if a tropical cyclone began on the last day of the month and continued into the next month for only two days, then it was attributed to the second month.

TABLE 3-2 LEGEND

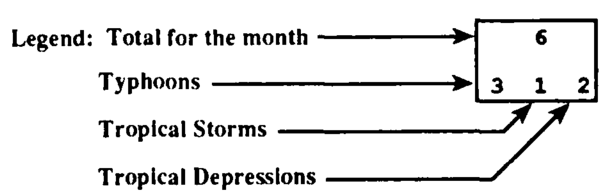


TABLE 3-2 **WESTERN NORTH PACIFIC TROPICAL CYCLONE DISTRIBUTION**

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
1959	0	1	1	1	0	1	3	8	9	3	2	2	31
	000	010	010	100	000	001	111	512	423	210	200	200	17 7 7
1960	1	0	1	1	1	3	3	9	5	4	1	1	30
	001	000	001	100	010	210	210	810	041	400	100	100	19 8 3
1961	1	1	1	1	4	6	5	7	6	7	2	1	42
	010	010	100	010	211	114	320	313	510	322	101	100	20 11 11
1962	0	1	0	1	3	0	8	8	7	5	4	2	39
	000	010	000	100	201	000	512	701	313	311	301	020	24 6 9
1963	0	0	1	1	0	4	5	4	4	6	0	3	28
	000	000	001	100	000	310	311	301	220	510	000	210	19 6 3
1964	0	0	0	0	3	2	8	8	8	7	6	2	44
	000	000	000	000	201	200	611	350	521	331	420	101	26 13 5
1965	2	2	1	1	2	4	6	7	9	3	2	1	40
	110	020	010	100	101	310	411	322	531	201	110	010	21 13 6
1966	0	0	0	1	2	1	4	9	10	4	5	2	38
	000	000	000	100	200	100	310	531	532	112	122	101	20 10 8
1967	1	0	2	1	1	1	8	10	8	4	4	1	41
	010	000	110	100	010	100	332	343	530	211	400	010	20 15 6
1968	0	1	0	1	0	4	3	8	4	6	4	0	31
	000	001	000	100	000	202	120	341	400	510	400	000	20 7 4
1969	1	0	1	1	0	0	3	3	6	5	2	1	23
	100	000	010	100	000	000	210	210	204	410	110	010	13 6 4
1970	0	1	0	0	0	2	3	7	4	6	4	0	27
	000	100	000	000	000	110	021	421	220	321	130	000	12 12 3
1971	1	0	1	2	5	2	8	5	7	4	2	0	37
	010	000	010	200	230	200	620	311	511	310	110	000	24 11 2
1972	1	0	1	0	0	4	5	5	6	5	2	3	32
	100	000	001	000	000	220	410	320	411	410	200	210	22 8 2
1973	0	0	0	0	0	0	7	6	3	4	3	0	23
	000	000	000	000	000	000	430	231	201	400	030	000	12 9 2
1974	1	0	1	1	1	4	5	7	5	4	4	2	35
	010	000	010	010	100	121	230	232	320	400	220	020	15 17 3
1975	1	0	0	1	0	0	1	6	5	6	3	2	25
	100	000	000	001	000	000	010	411	410	321	210	002	14 6 5
1976	1	1	0	2	2	2	4	4	5	0	2	2	25
	100	010	000	110	200	200	220	130	410	000	110	020	14 11 0
1977	0	0	1	0	1	1	4	2	5	4	2	1	21
	000	000	010	000	001	010	301	020	230	310	200	100	11 8 2
1978	1	0	0	1	0	3	4	8	4	7	4	0	32
	010	000	000	100	000	030	310	341	310	412	121	000	15 13 4
1979	1	0	1	1	2	0	5	4	6	3	2	3	28
	100	000	100	100	011	000	221	202	330	210	110	111	14 9 5
1980	0	0	1	1	4	1	5	3	7	4	1	1	28
	000	000	001	010	220	010	311	201	511	220	100	010	15 9 4
1981	0	0	1	1	1	2	5	8	4	2	3	2	29
	000	000	100	010	010	200	230	251	400	110	210	200	16 12 1
1982	0	0	3	0	1	3	4	5	6	4	1	1	28
	000	000	210	000	100	120	220	500	321	301	100	100	19 7 2
1983	0	0	0	0	0	1	3	6	3	5	5	2	25
	000	000	000	000	000	010	300	231	111	320	320	020	12 11 2
1984	0	0	0	0	0	2	5	7	4	8	3	1	30
	000	000	000	000	000	020	410	232	130	521	300	100	16 11 3
1985	2	0	0	0	1	3	1	7	5	5	1	2	27
	020	000	000	000	100	201	100	520	320	410	010	110	17 9 1
1986	0	1	0	1	2	2	2	5	2	5	4	3	27
	000	100	000	100	110	110	200	410	200	320	220	210	19 8 0
1987	1	0	0	1	0	2	4	4	7	2	3	1	25
	100	000	000	010	000	110	400	310	511	200	120	100	18 6 1
1988	1	0	0	0	1	3	2	5	8	4	2	1	27
	100	000	000	000	100	111	110	230	260	400	200	010	14 12 1
1989	1	0	0	1	2	2	6	8	4	6	3	2	35
	010	000	000	100	200	110	231	332	220	600	300	101	21 10 4
(1959-1989)													
MEAN:	0.6	0.3	0.6	0.7	1.3	2.1	4.5	6.2	5.7	4.6	2.8	1.5	30.8
CASES:	18	9	18	23	39	65	140	193	176	142	86	45	954

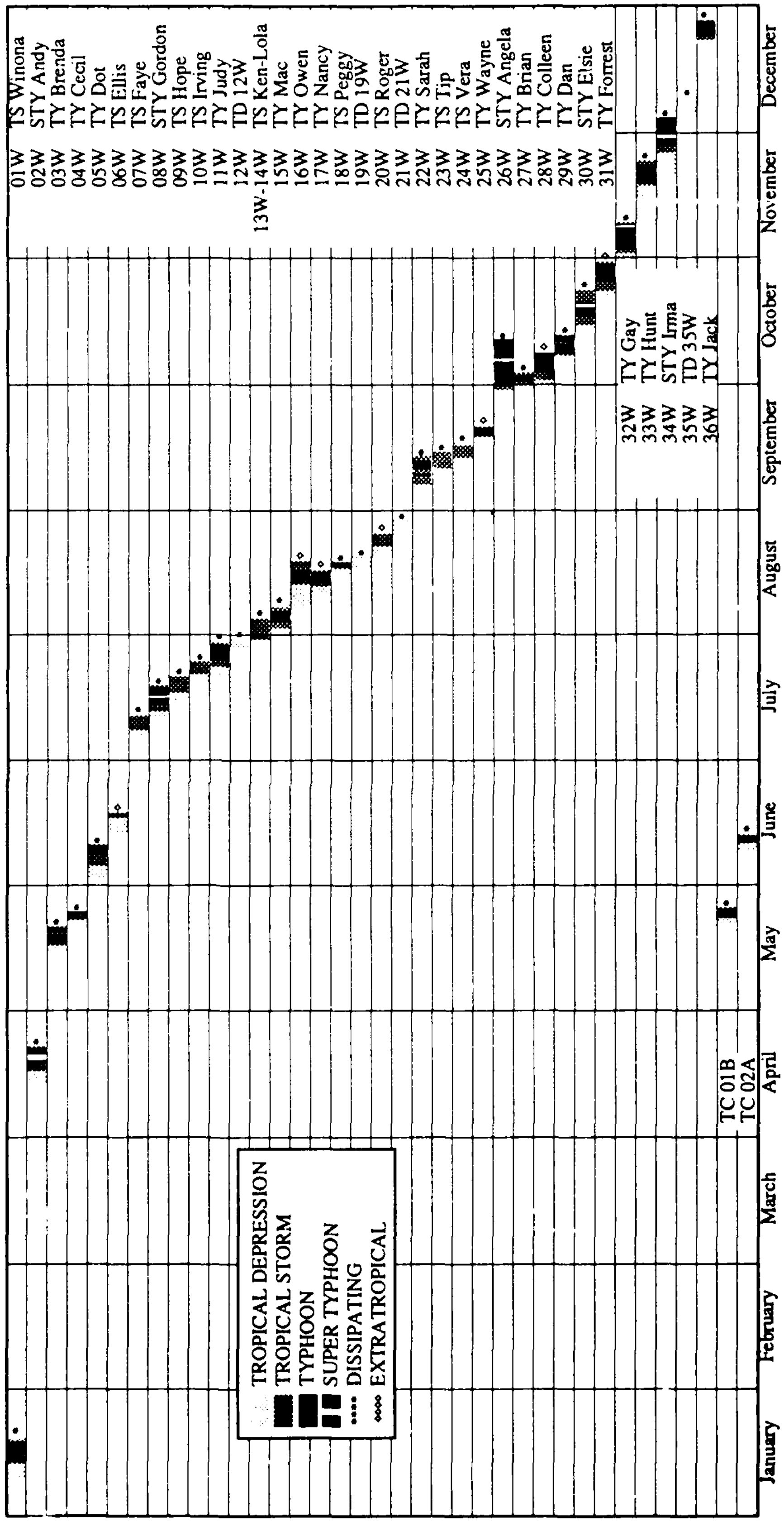


Figure 3-1. Chronology of western North Pacific and North Indian Ocean tropical cyclones for 1989.

TABLE 3-3 **WESTERN NORTH PACIFIC TROPICAL CYCLONES**

TYPHOONS

(1945 - 1958)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN:	0.4	0.1	0.3	0.4	0.7	1.1	2.0	2.9	3.2	2.4	2.0	0.9	16.3
CASES:	5	1	4	5	10	15	28	41	45	34	28	12	228

(1959 - 1989)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN:	0.3	0.1	0.2	0.5	0.7	1.0	2.7	3.2	3.2	3.1	1.7	0.7	17.4
CASES:	8	2	6	16	22	32	83	99	100	97	53	21	539

TROPICAL STORMS AND TYPHOONS

(1945 - 1958)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN:	0.4	0.1	0.4	0.5	0.8	1.6	3.0	3.9	4.1	3.3	2.8	1.1	22.0
CASES:	6	1	6	7	11	22	42	54	58	46	39	16	308

(1959 - 1989)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN:	0.5	0.3	0.5	0.7	1.0	1.8	4.1	5.3	5.0	4.1	2.6	1.3	27.6
CASES:	17	9	14	22	33	55	127	166	154	128	81	39	855

FORMATION ALERTS: 32 OF 51 INITIAL FORMATION ALERTS DEVELOPED INTO SIGNIFICANT TROPICAL CYCLONES (NOT INCLUDING THREE ON SYSTEMS THAT REGENERATED). TROPICAL CYCLONE FORMATION ALERTS WERE NOT ISSUED FOR TROPICAL CYCLONES 08W, 25W AND 34W.

WARNINGS DAYS:
- NUMBER OF CALENDAR WARNING DAYS: 154
- NUMBER OF CALENDAR WARNING DAYS WITH TWO TROPICAL CYCLONES: 46
- NUMBER OF CALENDAR WARNING DAYS WITH THREE TROPICAL CYCLONES: 9

TABLE 3-4 **TROPICAL CYCLONE FORMATION ALERTS WESTERN NORTH PACIFIC OCEAN**

YEAR	INITIAL TCFAS	TROPICAL CYCLONES WITH TCFAS	TOTAL TROPICAL CYCLONES	FALSE ALARM RATE
1975	34	25	25	26%
1976	34	25	25	26%
1977	26	20	21	23%
1978	32	27	32	16%
1979	27	23	28	15%
1980	37	28	28	24%
1981	29	28	29	3%
1982	36	26	28	28%
1983	31	25	25	19%
1984	37	30	30	19%
1985	39	26	27	33%
1986	38	27	27	29%
1987	31	24	25	23%
1988	33	26	27	21%
1989	51	32	35	32%
(1975-1989)				
MEAN:	34.3	26.1	27.5	23.9%
TOTALS:	515	392	412	

3.2 WESTERN NORTH PACIFIC TROPICAL CYCLONES

1989 was unique in many regards. The monsoon trough was very active, even into November. Because the trough was extremely broad and because of the abnormally large diurnal fluctuations in convection, disturbances were slow to develop to intensities above 30 to 40 kt (15 to 20 m/sec). As a result, JTWC used the new 36-hour Tropical Depression Warning on systems not expected to reach tropical storm intensity within 48 hours. The mid-tropospheric ridge was narrow — averaging less than 250 nm (465 km). This made forecasts, even for straight running tropical cyclones difficult. There were a large number of erratically moving cyclones with tracks containing several bifurcation points where difficult forecast decisions had to be made as to significant changes in direction of motion. Several tropical cyclones stalled for prolonged periods of time. Some examples are Typhoons Gay (32W), Irma (34W), Mac (15W) and Jack (36W), among others. In fact, Jack (36W) sat 175 nm (325 km) directly east of Guam for nearly two days. JTWC experienced several occasions where tropical cyclones engaged in binary interaction with each other or with other circulations in the environment. Most notable was the interaction between Typhoons Owen (16W), Nancy (17W) and towards the end Tropical Storm Peggy (18W). The Tropical Upper-Tropospheric Trough (TUTT) was extremely active and played a major role in the development, intensification and movement of numerous tropical cyclones. Of particular interest was Typhoon Gordon (08W) which actually developed explosively from a thunderstorm that built beneath, and directly up into a cold-cored TUTT low aloft. And finally, 1989 had a large number of very compact, yet very intense typhoons. The presence of Tropical Cyclone 32W (Gay) with super typhoon intensity in the Bay of Bengal was a rare occurance. The variety of synoptic influences on the 1989 tropical cyclone season made it one of the most unique and challenging in JTWC's 30-year history.

JANUARY THROUGH JUNE

The first western North Pacific tropical cyclone of 1989, **Winona (01W)**, quietly began in the eastern North Pacific southeast of the Hawaiian Islands. The system was unusual because of its compact size and persistence. In two weeks it traveled over 5500 nm (10,185 km) before finally dissipating in the Philippine Islands. Following Tropical Storm Winona (01W), there was a long break in activity until mid-April when **Andy (02W)** developed. Super Typhoon Andy (02W) was the second typhoon in the past nine years to form in April, the first super typhoon of 1989, and the first typhoon of the year to seriously threaten Guam. It developed very slowly, and after recurving at the extremely low latitude of 10° north, passed 70 nm (130 km) southeast of Guam. A month later **Brenda (03W)**, the first of two typhoons to form in May, generated in the western Caroline Islands, moved northwestward across the central Philippine Islands, and then made landfall in China. It was the second of eleven tropical cyclones to cross the Philippines during the year. An extensive monsoon trough spread across the Bay of Bengal into the South China Sea. Typhoon Brenda (03W) formed at the end of the trough. As Brenda (03W) moved northwestward and dissipated over southern China, it left behind an area of enhanced low-level southwesterly flow. Typhoon **Cecil (04W)** developed in the South China Sea in the wake of the enhanced flow from Typhoon Brenda (03W). After Cecil (04W) churned across the South China Sea and into Vietnam during the last week of May , the tropics were relatively quiet for two weeks. Then came Typhoon **Dot (05W)**, the first of two significant tropical cyclones in June. Dot (05W) formed in low latitudes south of the central Caroline islands, moved steadily west-northwestward and crossed the Philippine Islands. It reached typhoon intensity in the South China Sea and eventually dissipated over northern Vietnam. The second tropical cyclone to form in June, Tropical Storm **Ellis (06W)** interrupted the series of "straight runners" that occurred from Brenda (03W) through Dot (05W). The asymmetric displace-

ment of a broad area of gale force winds away and to the east of the low-level circulation center accompanied Ellis (06W). After five days as a poorly defined system, Ellis (06W) briefly peaked at tropical storm intensity before becoming extratropical and making landfall in Japan.

JULY

After another two-week break in activity, a surge in the southwest monsoon caused widespread convective activity in the area west of the Mariana Islands, culminating in the genesis of **Faye (07W)**, the first of seven tropical cyclones to form in July. Faye (07W) intensified at a normal rate as it tracked west-northwestward towards the Philippines. The cyclone weakened as it crossed north-central Luzon and reintensified slightly in the South China Sea. It weakened again in the central South China Sea, and crossed the island of Hainan before making landfall on the coast of northern Vietnam. At the start of the second week of July, while Tropical Storm Faye (07W) was affecting the Philippine Islands and the Tropical Upper-Tropospheric Trough (TUTT) was influencing weather near Wake Island, the second super typhoon of the year, **Gordon (08W)**, developed. It was unique in that it developed from a single cumulonimbus directly beneath a cyclonic cell in the TUTT. The cumulonimbus was initially small, but underwent a dramatic rapid, almost explosive, deepening phase. **Hope (09W)** generated in the wake of Gordon (08W) in a broad area of convection enhanced by divergence aloft associated with a TUTT cell. Hope (09W) failed to develop to typhoon intensity as a result of the upper-level shear caused by the outflow from Super Typhoon Gordon (08W). During its life, Hope (09W) moved generally northwestward , occasionally "stair stepping" in response to the passage of a series of mid-latitude shortwave troughs. Although no binary interaction was apparent, the tropical cyclone tracked along the periphery of Gordon's (08W) low-level circulation for most of its lifetime. As Super Typhoon Gordon (08W) was about to make landfall on the coast of China and Tropical Storm Hope (09W) was reaching peak intensity, **Irving (10W)** formed in the monsoon trough near the southwestern Caroline Islands. Tropical Storm Irving (10W) was the fourth tropical cyclone of 1989 to cross the South China Sea and the last to enter the South China Sea until Typhoon Brian (27W) late in September. Irving was short-lived and actually reached its maximum intensity as it made landfall on the coast of northern Vietnam. The day after Irving (10W) developed in the western Caroline Islands, **Judy (11W)** developed in the monsoon trough just west of Guam. The second of two typhoons to develop during the month of July, Judy (11W), followed a north-oriented track with a critical turn to the northwest, just to the south of Honshu. It brushed by the southern coast of Kyushu, made landfall on the south coast of the Korean Peninsula and dissipated rapidly. After a major track change on 26 July, it took JTWC a day to get the forecast back on track to the northwest. This situation highlighted the value of the alternate scenario and rapid telephone communications between the customer and the forecaster when forecast difficulties arise. While Typhoon Judy (11W) was tracking northwestward towards Korea, an associated area of deep convection became persistent to the south-southeast in the monsoon trough that had already proven itself the most active since July 1973. The disturbance became **Ken-Lola (13W-14W)** and took an elongated cycloidal track, passing close to Okinawa before making landfall on the coast of eastern China. While in warning status, JTWC considered the system as two separate tropical cyclones. A detailed post-analysis, even though not absolutely conclusive, strongly suggested that Tropical Storms Ken (13W) and Lola (14W) were most probably the same system. Tropical Storm Ken-Lola (13W-14W) underscored the limitations of remote sensing for locating some poorly organized systems. Synoptic data proved invaluable in identifying and classifying the system while in warning status and in post-analysis. A much larger mid-level cy-clone in which the tropical cyclone was embedded appeared to be the major influence on Ken-

Lola's (13W-14W) track.

AUGUST

As the most active July since 1973 came to a close, Typhoon Judy (11W) was dissipating over Korea and Tropical Storm Ken-Lola (13W-14W) was threatening Okinawa. During this time, **Mac (15W)** developed northeast of Saipan in an extremely active monsoon trough that extended as far east as Wake Island. Typhoon Mac (15W) also developed at a higher than normal latitude. In addition, its track and intensity were influenced by a complex mid-latitude synoptic regime and complicated by a multi-storm environment. The typhoon had a general northwest track, interrupted by 48 hours of westward movement before it resumed an accelerated north orientated track, and made landfall east of Tokyo. Mac (15W) weakened rapidly as it moved into and across the Sea of Japan and dissipated over southern Sakhalin Island. Soon thereafter, Typhoon **Owen (16W)** slowly spun up in the monsoon trough while moving on a general northwestward to northward track. Due to the proximity of **Nancy (17W),** which developed at the extreme eastern end of the monsoon trough and was intensifying to the east, Owen (16W) took more than a week to reach tropical storm intensity. Later, Owen's (16W) three days of binary interaction with Typhoon Nancy (17W) resulted in an unusual southeasterly track during its developing stage. Then, the tropical cyclone followed Nancy (17W) through recurvature, extratropical transition and into high latitudes. The third tropical cyclone to develop in the monsoon trough, was **Peggy (18W).** After a brief interaction with Owen (16W), Peggy (18W) was short-lived and only reached minimal tropical storm intensity. Then came **Tropical Depression 19W** with its unusual curved track to the north, west, and then south which appeared to coincide with the overall motion displayed by a larger, mid-level low. As the mid-level low began to fill, the tropical depression escaped its influence, and the track of the cyclone straightened out, moving westward within the easterly steering flow. Forming just north of Taiwan, **Roger (20W)** moved south-eastward into the southern Ryukyu's, abruptly turned northeastward, and made landfall on Honshu. At the start, the forecast problem for this tropical cyclone was exacerbated by the difficulty in locating the system's complex center during its formative stages and the immediate threat it posed to DOD assets on Okinawa. The eighth and final tropical cyclone of August, **Tropical Depression 21W**, developed on the eastern end of the monsoon trough which was located to the northeast of the Mariana Islands. Because JTWC recognized that intensification would be inhibited by strong vertical wind shear, only Tropical Depression Warnings were issued.

SEPTEMBER

The first of the September tropical cyclones, **Sarah (22W)** proved to be a bona fide challenge to forecasters. The cyclone apparently underwent a binary interaction with a secondary low east of Luzon and later, when it stalled east of Luzon, was involved with the development of a sympathetic low on the lee side of Luzon. From genesis involving two distinct cloud masses to accelerating toward the Philippines, stalling just east of Luzon, moving north and rapidly reintensifying, then looping over eastern Taiwan, Sarah (22W) was one of the most difficult storms of the year to forecast. Sarah (22W) finally moved northwestward across northern Taiwan and dissipated in China. Generating in early September at the eastern end of the monsoon trough, **Tip (23W)** executed an unusual track to the northeast, then recurved after moving northwestward around the subtropical ridge, and finally tracked eastward with the polar westerlies. Tropical Storm Tip (23W) reached its peak intensity at 37° north latitude, two days after recurvature. Developing in the monsoon trough north of Guam, Tropical Storm **Vera (24W),** after some initial erratic motion, moved on a west-northwestward track, threatened Okinawa, and made a devastating landfall just south of Shanghai. About 24 hours after Tropical Storm Vera (24W) had dissipated over eastern China,

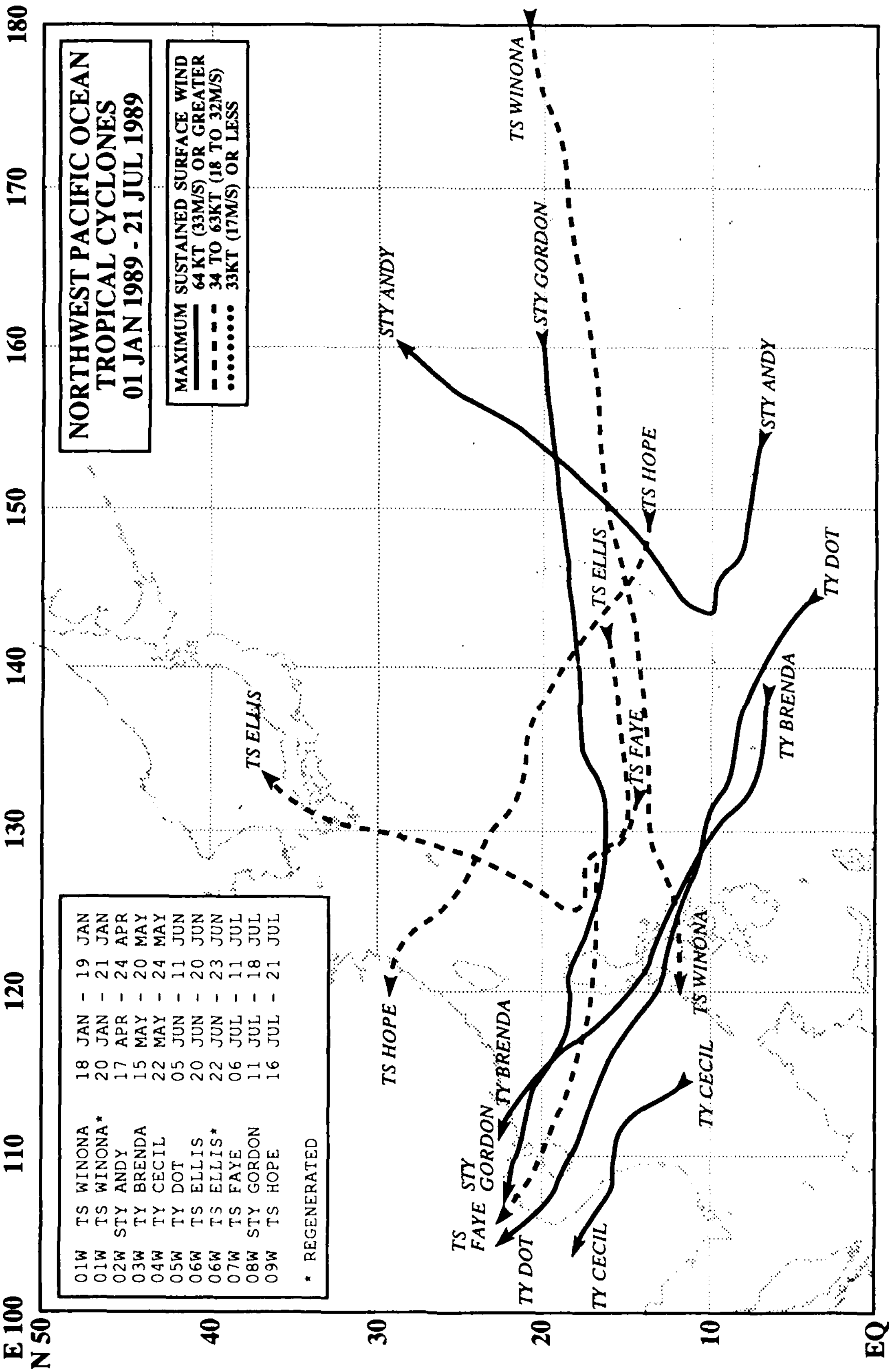
the first warning on **Wayne (25W)** was issued. The last of four tropical cyclones to mature in September, Typhoon Wayne (25W) was also the last tropical cyclone of 1989 to affect Japan. It was unique in that it intensified after recurvature, partly as a result of its rapid acceleration. Wayne (25W) caused considerable destruction, mudslides and some deaths in Japan.

OCTOBER

During late September, the monsoon trough, located near 10° north latitude, became very active after a week of little convective activity. The first tropical cyclone of a three-cyclone outbreak in the monsoon trough during a three-day period, **Angela (26W)** had the unique distinction of being in warning status longer than any other tropical cyclone in the western North Pacific this year — 12 days. JTWC issued a total of 46 warnings on this typhoon. Angela (26W) was also one of five tropical cyclones to reach super typhoon intensity in 1989. Developing south of Guam, Angela (26W) tracked slowly westward and struck northern Luzon with super typhoon intensity causing a large number of casualties and widespread destruction. It then continued into the South China Sea, where it reintensified, and finally made landfall in central Vietnam. As Angela (26W) developed over the Philippine Sea, the monsoon trough became active across the South China Sea from western Luzon to Vietnam and spawned typhoon **Brian (27W)**. Typhoon Cecil (04W) in May and Brian (27W) in late September and early October were the only tropical cyclones of the year to develop and spend their entire lifetimes within the confines of the South China Sea. Nearly 4000 nm (7400 km) to the east, a deep trough penetrated into the tropical western North Pacific near the dateline and **Colleen (28W)** formed at the base of the trough. Colleen (28W) passed through the northern Mariana Islands before recurving south of Japan. The tropical cyclone maintained typhoon intensity until it completed extratropical transition, threatening PACEX 89 — the largest US Navy exercise conducted in the Pacific since the Korean War. Colleen (28W) highlighted the difficulty of tracking poorly organized systems with only nighttime infrared satellite imagery, but also showed the value of data from the microwave imager as a tool to help locate these systems. Forming from a disturbance in the monsoon trough near Truk in the central Caroline Islands, **Dan (29W)** followed a steady west-northwestward track and crossed the central Philippine Islands. Coming just days after Typhoon Angela's (26W) destructive passage across northern Luzon, Dan (29W) added to the misery heaped on the Philippines by its predecessor. The cyclone reintensified in the South China Sea and made landfall on the coast of central Vietnam where it caused more destruction. In the wake of Super Typhoon Angela (26W) and Typhoon Dan (29W), Super Typhoon **Elsie (30W)** became the third tropical cyclone to hit the Philippine Islands within 12 days. Elsie (30W) developed from a TUTT-induced wave in the easterlies and tracked westward throughout its life. In the Philippine Sea, Elsie (30W) rapidly intensified and struck central Luzon with an intensity of 140 kt (72 m/sec). It was cited as the most intense cyclone to strike the Philippine Islands this year. Because of its small size, Elsie (30W) weakened dramatically as it moved across the Philippines, and did not reintensify as it traversed the South China Sea. The cyclone dissipated after making landfall in central Vietnam. The last of six tropical cyclones in October and the 17th cyclone of at least typhoon intensity for the year, **Forrest (31W)** was slow and erratic in its development. Throughout its early life, Forrest (31W) was a sloppy, broad system. After passing Guam, Forrest (31W) finally intensified and ultimately became a respectable 95-kt (49-m/sec) typhoon. Soon thereafter, it recurved and accelerated rapidly to the northeast becoming one of the year's strongest extratropical cyclones.

NOVEMBER THROUGH DECEMBER

The first tropical cyclone of November turned out to be the worst tropical cyclone to affect the Malay Peninsula in 35 years. **Gay (32W)** generated in the Gulf of Thailand, sank numerous ships, crossed the Malay Peninsula into the Bay of Bengal and slammed into India with peak sustained winds of 140 kt (70 m/sec). Unique because of its small size, great intensity, and point of origin, Gay (32W) challenged forecasters by crossing two different tropical cyclone basins and almost entering a third. Except for Typhoon Gay (32W), early November was relatively inactive in the western North Pacific. In mid-November, **Hunt (33W)** initially appeared as a weak tropical disturbance in the monsoon trough. Hunt (33W) was the fourth typhoon, following Angela (26W), Dan (29W) and Elsie (30W), to strike the Philippine Islands within six weeks. Generally a westward moving system, Hunt (33W) was slow to develop, but intensified rapidly in the western Philippine Sea. As it approached the Philippines, the cyclone underwent a "stair step" before resuming a westward course into central Luzon. Unlike its predecessors, Hunt (33W) dissipated in the South China Sea after crossing Luzon. **Irma (34W)** was the third and final tropical cyclone to form in November. It's development and track were dictated by complex mid-latitude and monsoonal regimes. Initially, Irma (34W) was slow to develop, however, rapid intensification followed once it entered in the Philippine Sea. Irma (34W) lasted 17 days and required a total of 39 warnings — only Super Typhoon Angela (26W) exceeded this longevity with its 46 warnings. As Super Typhoon Irma (34W) weakened in the Philippine Sea, **Tropical Depression 35W** was detected on the first day of December in the western Marshall Islands. The depression lasted more than a week as a discrete system, although it was in warning status only 48 hours. The second tropical cyclone to form in December, **Jack (36W)** was the twenty-first tropical cyclone of the year to attain at least typhoon intensity, and was the final tropical cyclone of the year. Typhoon Jack (36W) was noteworthy for the unusually long period it remained stationary. Not surprisingly, the unusual motion of Typhoon Jack (36W) was accompanied by an equally unusual intensification and dissipation pattern. The cyclone rapidly intensified from 30 to 125 kt (15 to 64 m/sec) in three and a half days, then fell apart completely. In this remarkable dissipation, Jack's (36W) maximum winds dropped from 105 to 30 kt (54 to 15 m/sec) in 24 hours.


NORTHWEST PACIFIC OCEAN
TROPICAL CYCLONES
01 JAN 1989 - 21 JUL 1989
MAXIMUM SUSTAINED SURFACE WIND
64 KT (33M/S) OR GREATER
34 TO 63KT (18 TO 32M/S)
33KT (17M/S) OR LESS
01W TS WINONA 18 JAN - 19 JAN
01W TS WINONA* 20 JAN - 21 JAN
02W STY ANDY 17 APR - 24 APR
03W TY BRENDA 15 MAY - 20 MAY
04W TY CECIL 22 MAY - 24 MAY
05W TY DOT 05 JUN - 11 JUN
06W TS ELLIS 20 JUN - 20 JUN
06W TS ELLIS* 22 JUN - 23 JUN
07W TS FAYE 06 JUL - 11 JUL
08W STY GORDON 11 JUL - 18 JUL
09W TS HOPE 16 JUL - 21 JUL
* REGENERATED
TS WINONA
STY GORDON
STY ANDY
TS HOPE
TS ELLIS
TY DOT
TY BRENDA
TS FAYE
TS WINONA
TY CECIL
TY BRENDA
STY GORDON
TS FAYE
TY DOT
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TS HOPE
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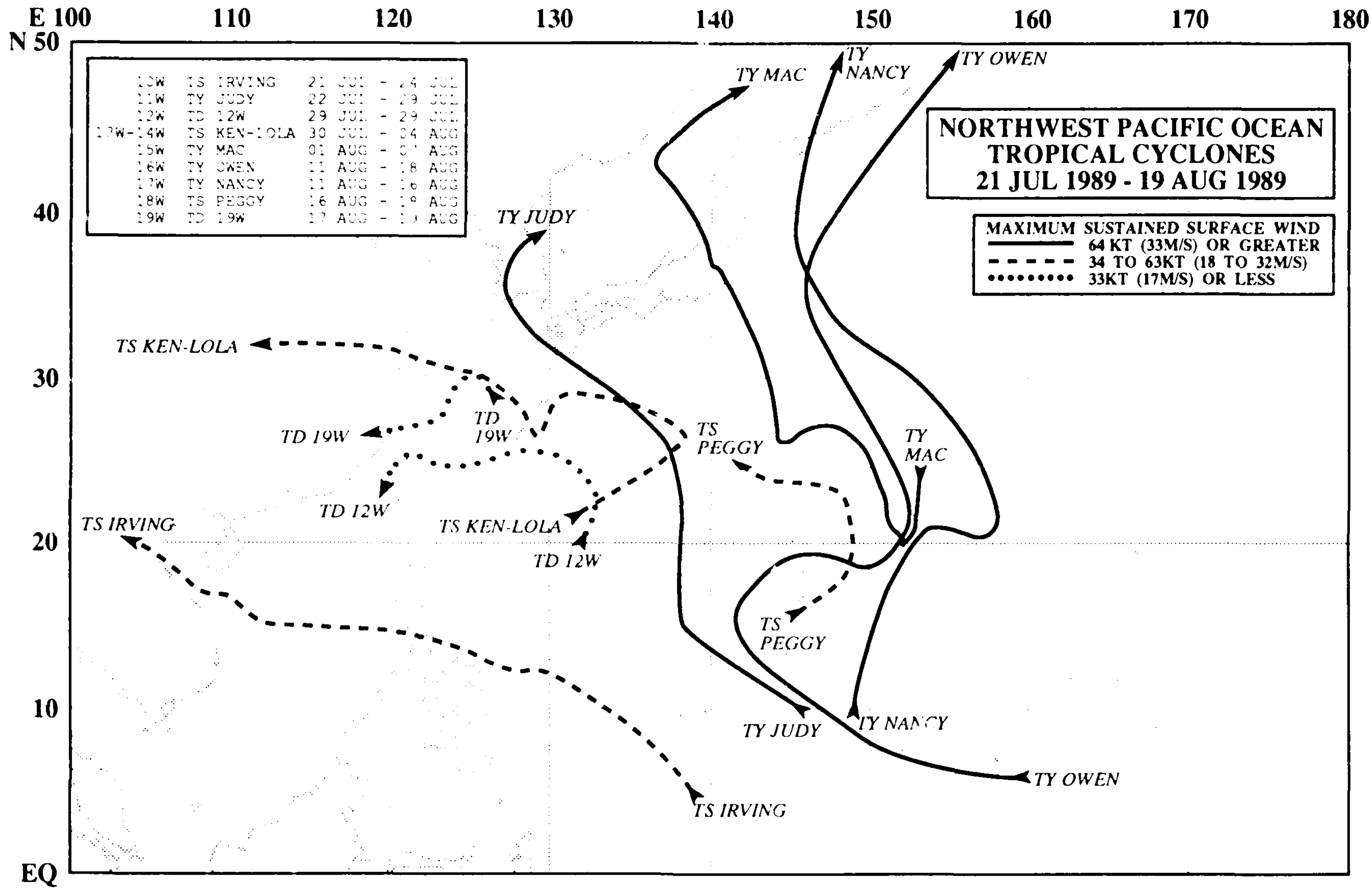
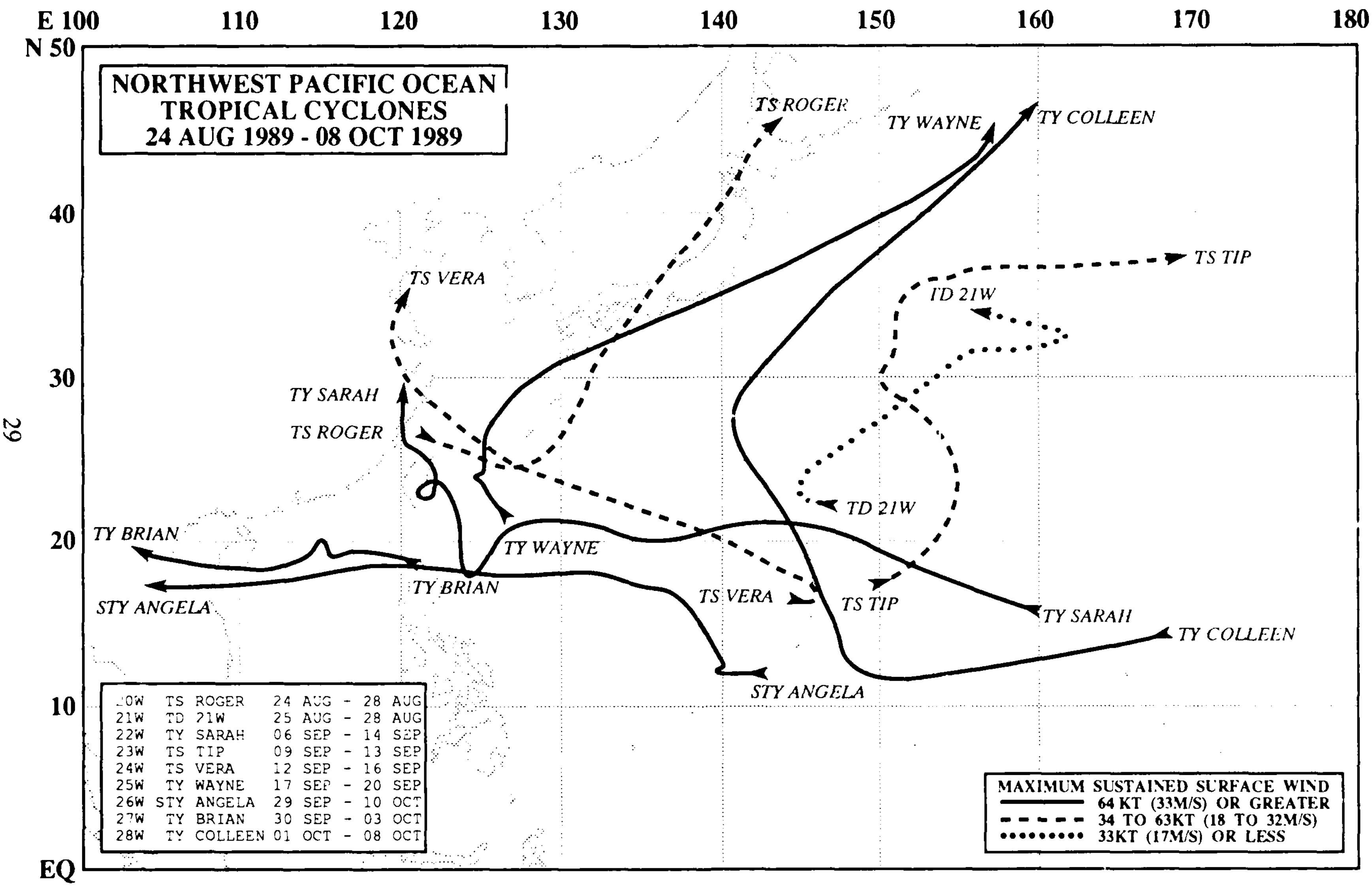
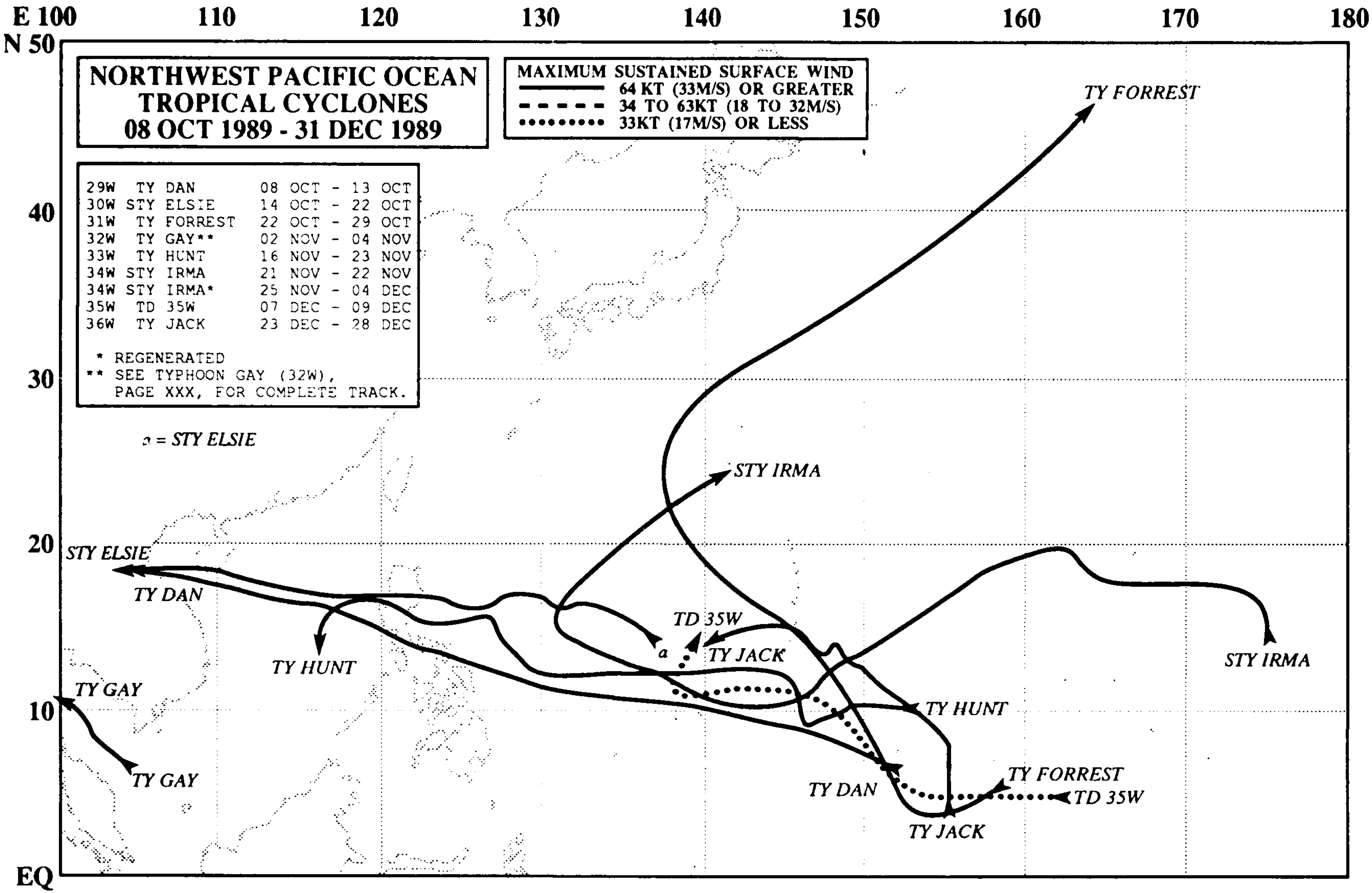

NORTHWEST PACIFIC OCEAN
TROPICAL CYCLONES
21 JUL 1989 - 19 AUG 1989
MAXIMUM SUSTAINED SURFACE WIND
64 KT (33M/S) OR GREATER
34 TO 63KT (18 TO 32M/S)
33KT (17M/S) OR LESS
10W TS IRVING 21 JUL - 24 JUL
11W TY JUDY 22 JUL - 29 JUL
12W TD 12W 29 JUL - 29 JUL
13W-14W TS KEN-LOLA 30 JUL - 04 AUG
15W TY MAC 01 AUG
16W TY OWEN 11 AUG - 18 AUG
17W TY NANCY 11 AUG - 16 AUG
18W TS PEGGY 16 AUG - 19 AUG
19W TD 19W 17 AUG
E 100
110
120
130
140
150
160
170
180
N 50
40
30
20
10
EQ
TY MAC
TY NANCY
TY OWEN
TY JUDY
TS KEN-LOLA
TD 19W
TS PEGGY
TY MAC
TD 12W
TS IRVING
TY JUDY
TY NANCY
TY OWEN
TS IRVING


NORTHWEST PACIFIC OCEAN
TROPICAL CYCLONES
24 AUG 1989 - 08 OCT 1989
E 100
110
120
130
140
150
160
170
180
N 50
40
30
20
10
EQ
TS ROGER
TY WAYNE
TY COLLEEN
TS VERA
TS TIP
TD 21W
TY SARAH
TS ROGER
TD 21W
TY BRIAN
TY WAYNE
TY BRIAN
STY ANGELA
TS VERA
TS TIP
TY SARAH
TY COLLEEN
STY ANGELA
20W TS ROGER 24 AUG - 28 AUG
21W TD 21W 25 AUG - 28 AUG
22W TY SARAH 06 SEP - 14 SEP
23W TS TIP 09 SEP - 13 SEP
24W TS VERA 12 SEP - 16 SEP
25W TY WAYNE 17 SEP - 20 SEP
26W STY ANGELA 29 SEP - 10 OCT
27W TY BRIAN 30 SEP - 03 OCT
28W TY COLLEEN 01 OCT - 08 OCT
MAXIMUM SUSTAINED SURFACE WIND
64 KT (33M/S) OR GREATER
34 TO 63KT (18 TO 32M/S)
33KT (17M/S) OR LESS


NORTHWEST PACIFIC OCEAN
TROPICAL CYCLONES
08 OCT 1989 - 31 DEC 1989
MAXIMUM SUSTAINED SURFACE WIND
64 KT (33M/S) OR GREATER
34 TO 63KT (18 TO 32M/S)
33KT (17M/S) OR LESS
29W TY DAN 08 OCT - 13 OCT
30W STY ELSIE 14 OCT - 22 OCT
31W TY FORREST 22 OCT - 29 OCT
32W TY GAY** 02 NOV - 04 NOV
33W TY HUNT 16 NOV - 23 NOV
34W STY IRMA 21 NOV - 22 NOV
34W STY IRMA* 25 NOV - 04 DEC
35W TD 35W 07 DEC - 09 DEC
36W TY JACK 23 DEC - 28 DEC
* REGENERATED
** SEE TYPHOON GAY (32W), PAGE XXX, FOR COMPLETE TRACK.
a = STY ELSIE
E 100
110
120
130
140
150
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170
180
N 50
40
30
20
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EQ
TY FORREST
STY IRMA
STY ELSIE
TY DAN
TY HUNT
TD 35W
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TY JACK
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TY FORREST
TD 35W
TY JACK

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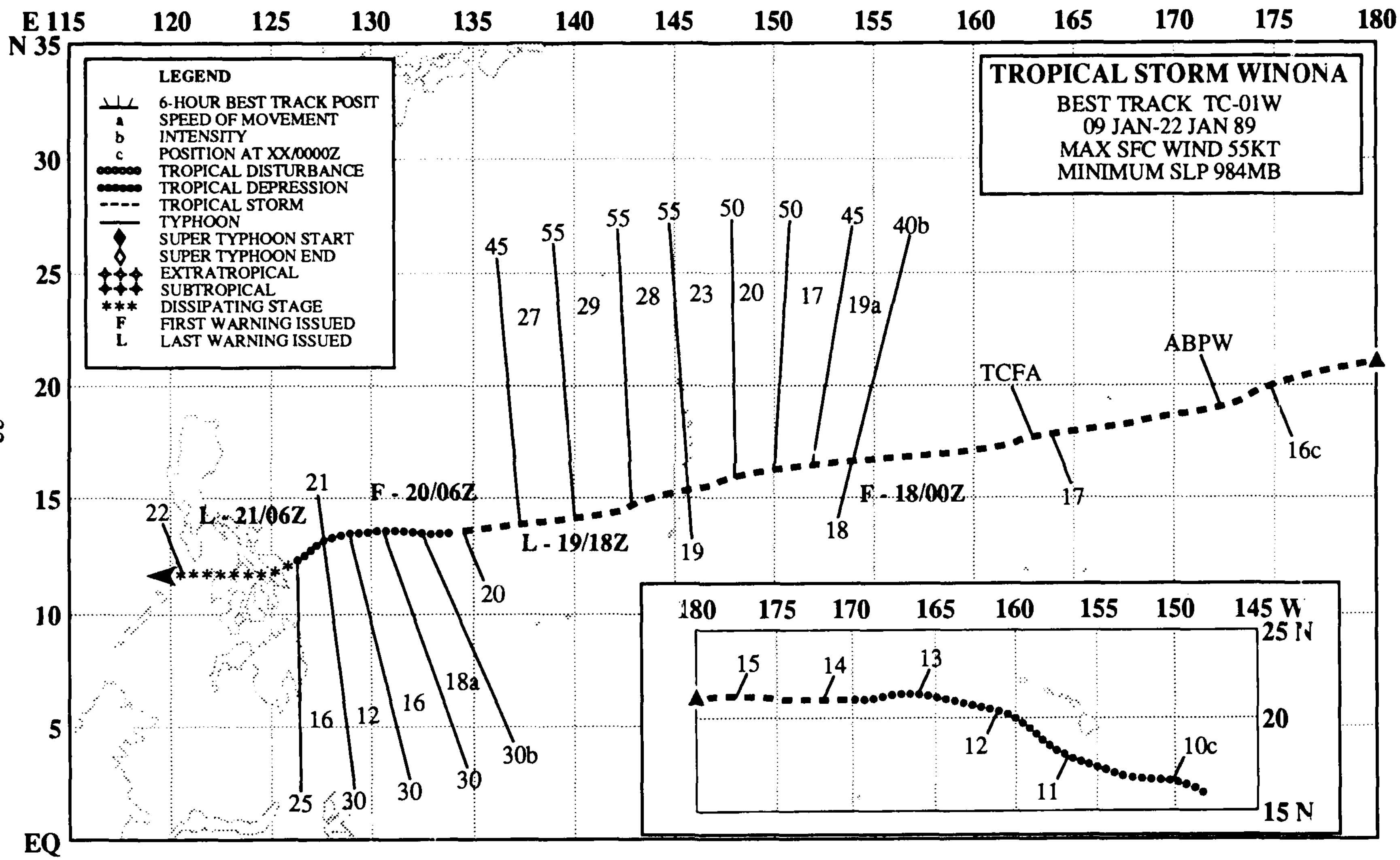
TROPICAL STORM WINONA
BEST TRACK TC-01W
09 JAN-22 JAN 89
MAX SFC WIND 55KT
MINIMUM SLP 984MB
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 115
120
125
130
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N 35
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TCFA
ABPW
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F - 18/00Z
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40b
19a
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27
45
L - 19/18Z
20
F - 20/06Z
21
22
L - 21/06Z
30b
18a
30
16
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12
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170
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160
155
150
145 W
25 N
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15 N
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10c

TROPICAL STORM WINONA (01W)

The first western North Pacific tropical cyclone of 1989, Winona quietly began in the eastern North Pacific southeast of the Hawaiian Islands. The system was unusual because of its compact size and persistence. In two weeks it traveled over 5500 nm (10,185 km) before finally dissipating in the Philippine Islands.

At the start of the second week of January, 40-kt (21-m/sec) upper-level westerly winds funneled through a trough located just east of the Hawaiian Islands and created a broad area of divergence aloft to the southeast. In response, an area of deep convection persisted under the divergence and over the east-southeasterly winter trades. As the upper-level trough relocated eastward at 091200Z, a swirl of low-level cloudiness (Figure 3-01-1) became exposed, leaving behind its convective cloudiness, and moved to the west-northwest as a wave until 11 January. Then the supporting convection flared up (Figure 3-01-2), triggering flash floods on Kauai. As the system assumed a more westward track on 12 January, it again passed under another upper-level trough. This time, however, the central convection persisted. Sparse surface data indicated a small area of light westerly winds to the south of the circulation center and a minimum sea-level pressure center of 1010 mb.

On 16 January, the compact system still retained its deep convection. It had traversed the Central Pacific in the dead of winter at 20° north latitude and persisted, which is extremely unusual. In fact, Winona was so unique that the analog and climatological forecast guidance was not available, or very limited, for most of the tropical cyclone's lifetime. It had crossed the international dateline the day before and was now approaching Wake Island. At 160600Z, the Significant Tropical Weather Advisory mentioned its persistent circulation and central convection. Later, at 161800Z, it was 75 nm (140 km) south of Wake Island (WMO 91245),

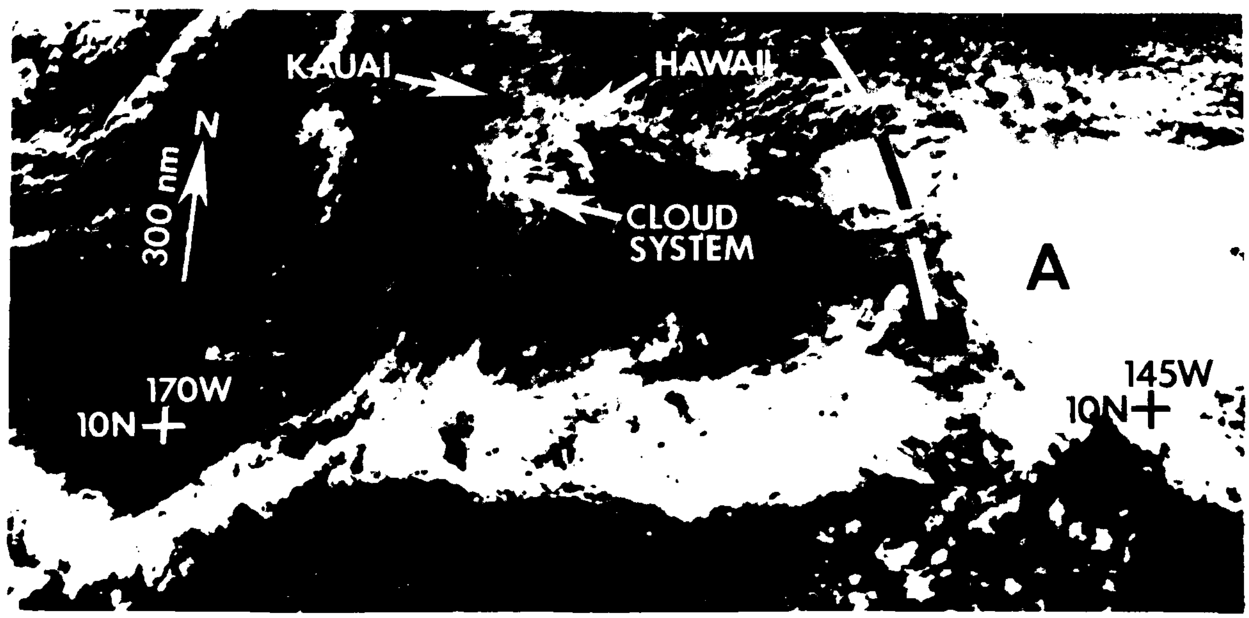

Figure 3-01-1. The low-level cloud system is passing south of the island of Hawaii. The area of bright cloudiness near point A is located east of the upper-level trough (102316Z January GOES West visual imagery courtesy of the National Weather Service Forecast Office, Honolulu, Hawaii).

which experienced maximum sustained surface winds of 25 kt (13 m/sec) and gradient-level winds (Figure 3-01-3) of 30 kt (15 m/sec).

After Winona passed Wake Island, a satellite intensity estimate of 25 kt (13 m/sec) coupled with the system's translational speed of more than 20 kt (37 km/hr) prompted a Tropical Cyclone Formation Alert at 170030Z. The subject of the Alert was upgraded to Tropical Storm Winona at 180000Z based on persistent central convection, the satellite intensity analysis and the cyclones rapid translational speed to the west, which would cause higher winds to the north of the circulation center. Since the tropical cyclone was embedded in broad easterly flow, a "straight runner" was forecast.

Just at the end of 18 January invaluable insight came from the ship **MV Williams** as follows, "Believe to have passed through center at 180700Z........Barometer pressure 991 (mb) max sustained winds 045 (gusts to) 65-70 kts, combined sea-swell 35 (ft)." This ship observation resulted in a warning and final best track intensity* increase (Figure 3-01-4). Without any additional direct measurements, satellite remote sensing tracked the cold cloud tops throughout the night. First light visual satellite data and later initial radar reports from Andersen AFB, Guam (WMO 91218) found Winona south and west of the expected track (Figure 3-01-5). The tropical storm (Figure 3-01-6) with peak winds of 55 kt (28 m/sec), passed just to the north of Saipan at 190000Z. The International Airport (91232) reported

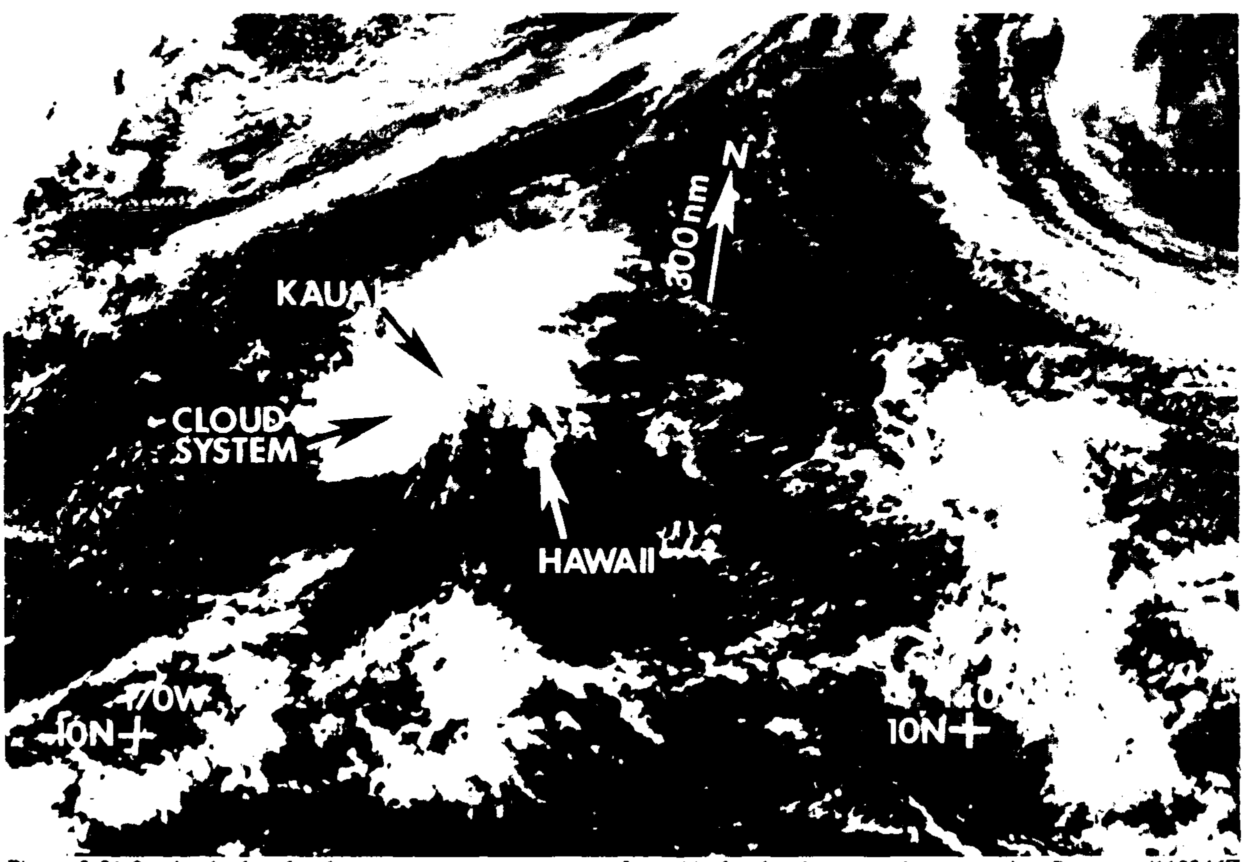

Figure 3-01-2. As the low-level vortex enters an area more favorable for development, the convection flares up (112346Z January GOES West visual imagery courtesy of the National Weather Service Forecast Office, Honolulu, Hawaii).

*This underscores a limitation of the Dvorak technique (1984), when applied to tropical cyclones that are moving along track at speeds greater than the climatic mean. Tropical cyclone forecasters should consider excess translational speed in addition to the intensity estimate, that is derived from the cloud signature, to better approximate maximum sustained surface winds.

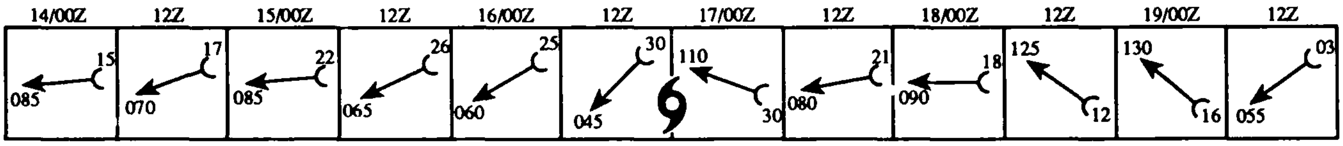

Figure 3-01-3. The gradient winds at Wake Island (91245) peak at 30 kt (15 m/sec) and undergo a directional change between 161200Z and 170000Z, as Winona passes to the south. Note the gradual speed increase from two days before Winona's passage and decrease for two days afterward.

winds of 25 kt (13 m/sec) with gusts to 35 kt (18 m/sec). No loss of life was reported Saipan.

Winona continued accelerating to the west-southwest along the southern edge of a shallow modifying polar air mass until the deep supporting convection was lost. A final warning was issued at 191800Z. However, the central convection flared up again and a regenerated warning followed at 200600Z. Just prior to landfall in the central Philippine Islands, Winona's deep central convection fell apart and the system was finalled at 210600Z.

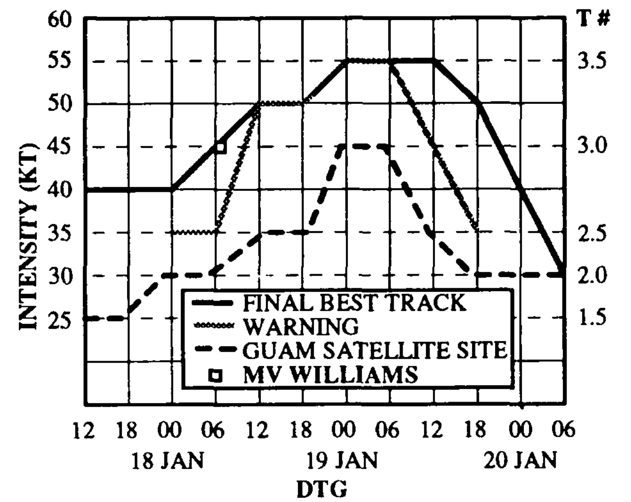

Figure 3-01-4. Impact of the ship **MV Williams'** 180700Z report on the warning and final best track intensities for Winona.

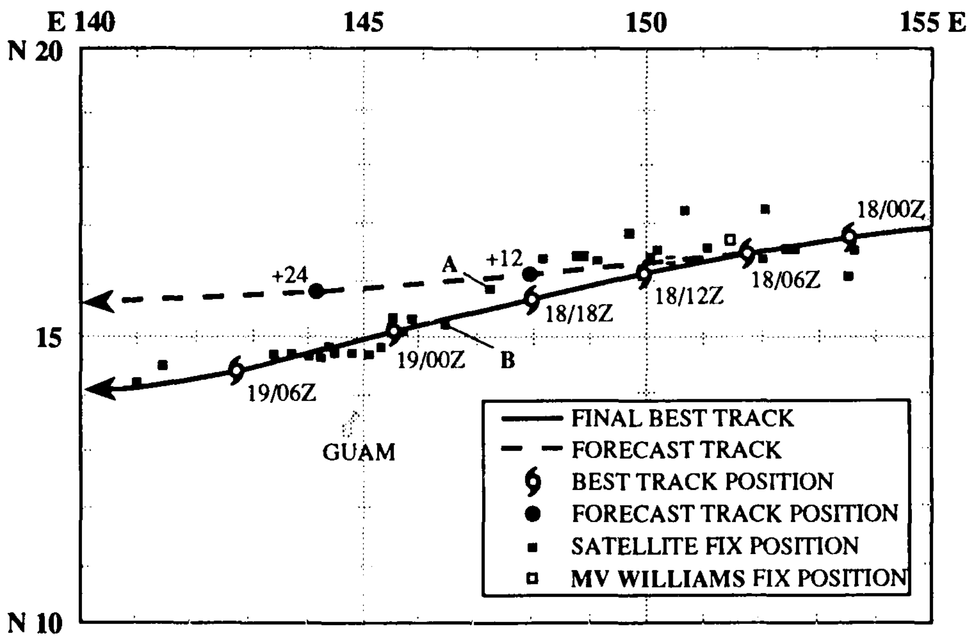

Figure 3-01-5. Comparison of expected track, raw fix data and final best track for Winona. The first daylight visual satellite fixes (A and B) were key elements in establishing Winona's continued movement to the west-southwest.

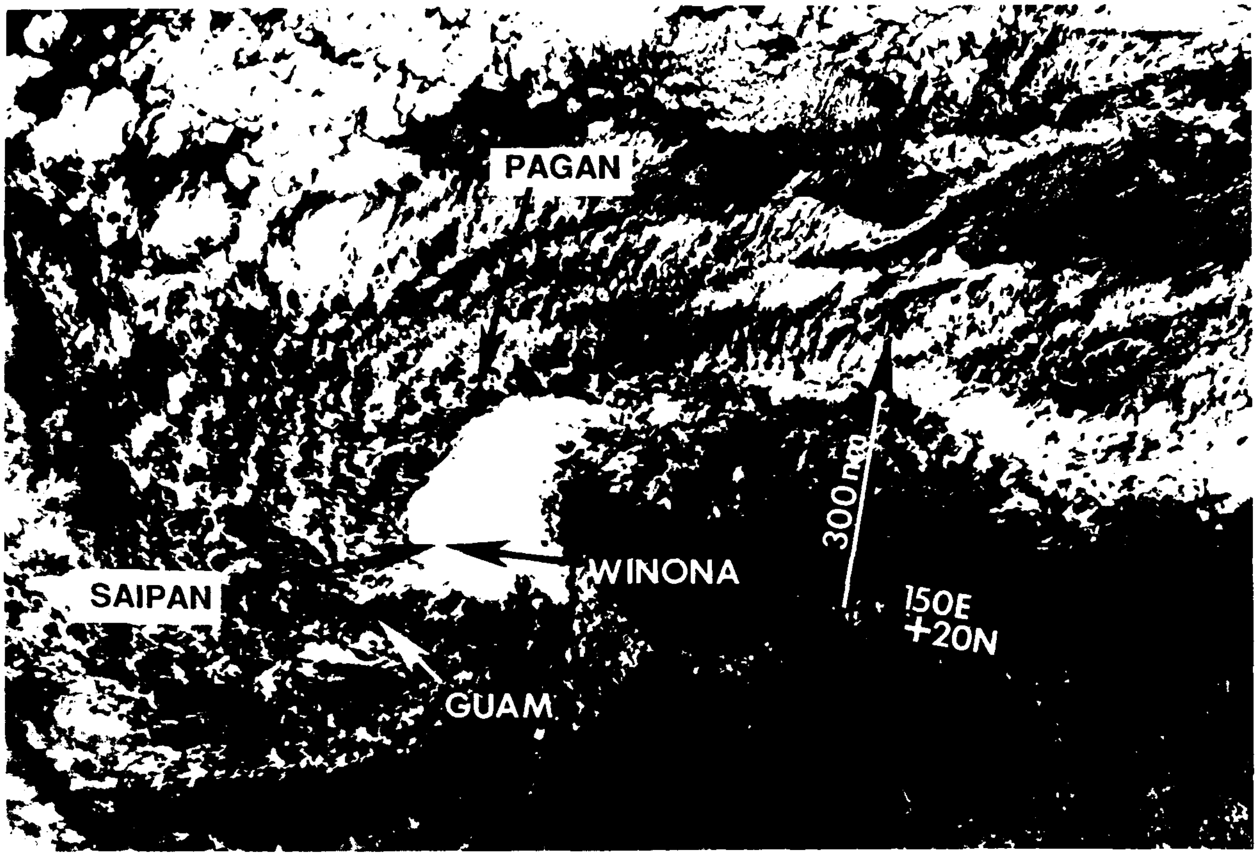

Figure 3-01-6. Tropical Storm Winona approaches Saipan. Note the compact size of the system (182321Z January DMSP visual imagery).

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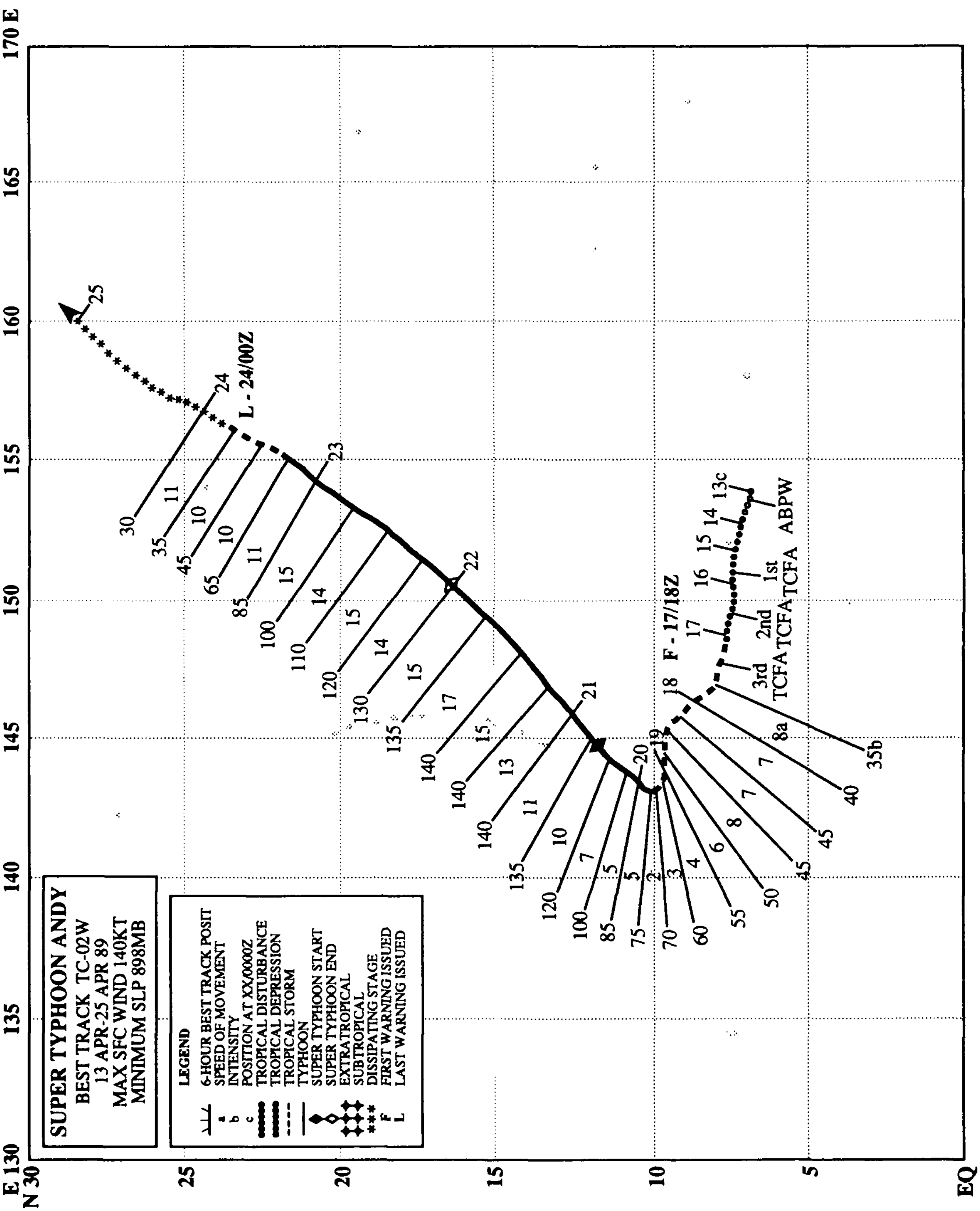


SUPER TYPHOON ANDY
BEST TRACK TC-02W
13 APR-25 APR 89
MAX SFC WIND 140KT
MINIMUM SLP 898MB
LEGEND
6-HOUR BEST TRACK POSIT
SPEED OF MOVEMENT
INTENSITY
POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
L - 24/00Z
F - 17/18Z
ABPW
1st TCFA
2nd TCFA
3rd TCFA
170 E
165
160
155
150
145
140
135
E 130
N 30
25
20
15
10
5
EQ

SUPER TYPHOON ANDY (02W)

For the western North Pacific, Andy was the second typhoon in the past nine years to form in April, the first super typhoon of 1989 and the first typhoon of the year to seriously threaten Guam.

The weather pattern the second week of April mirrored climatology with brisk, east-northeast trade winds dominating the low latitudes and only token deep convection. However, by the close of the week, the trade winds became lighter and equatorial westerlies replaced the cross-equatorial flow, or buffer, as Tropical Cyclone 26S (Orson) developed south of the equator in the Arafura Sea. North of the equator increased convection persisted near Truk Atoll in the eastern Caroline Islands. This increased convection was first mentioned in the Significant Tropical Weather Advisory at 130600Z. Continued cloud development prompted the first Tropical Cyclone Formation Alert at 151430Z. Intensification of the system (Figure 3-02-1) was slow, however, and follow-on Alerts were issued at 161430Z and 171430Z.

As this area slowly moved westward and gradually intensified, it was finally upgraded at 171800Z to Tropical Depression 02W. Data from the Automated Meteorological Observing Station (AMOS) installed in 1988 on Faraulep Island (WMO 52005) in the central Carolines became very important as it monitored the

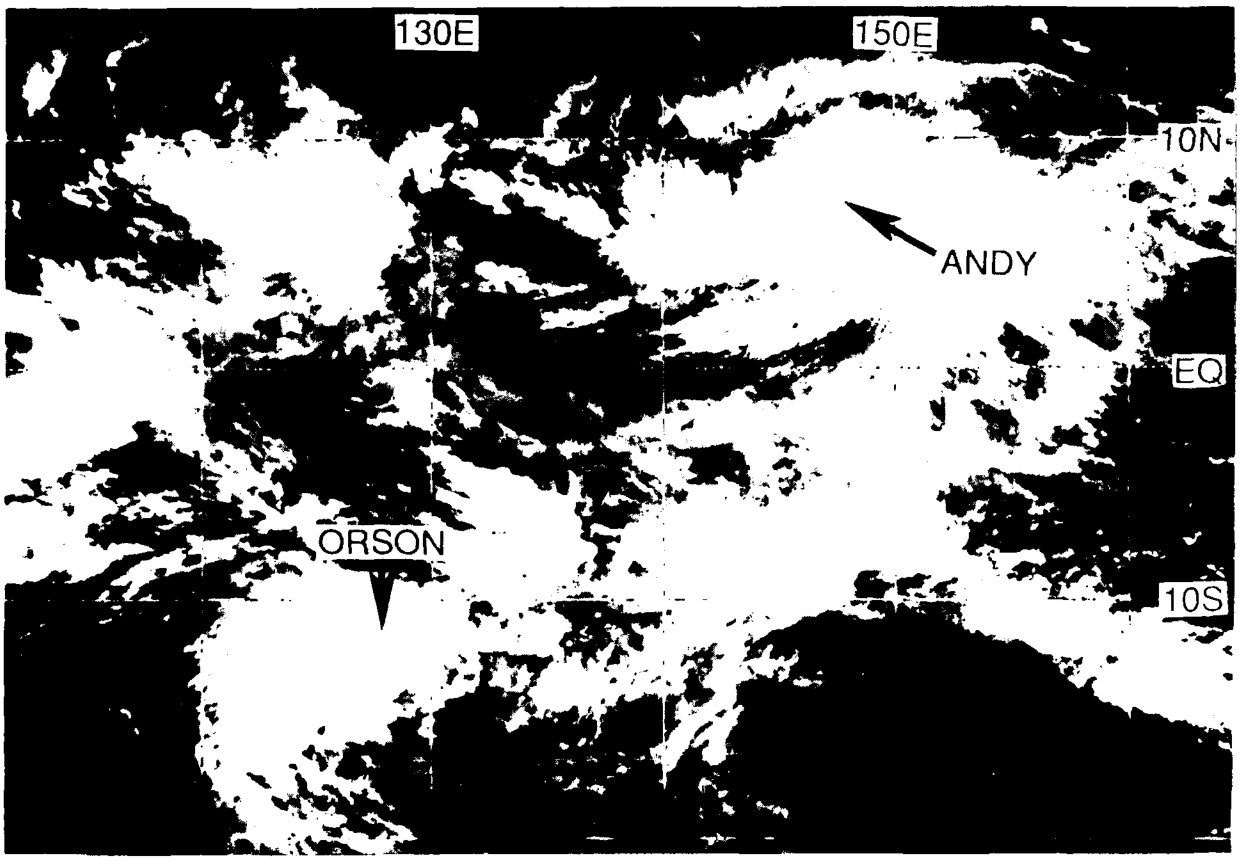


Figure 3-02-1. Satellite global data base display from the Air Force Global Weather Central captures the two tropical cyclones — Andy near Truk and Orson (26S) in the Arafura Sea (170000Z April DMSP infrared imagery).

approach of the tropical cyclone (Figure 3-02-2). In this normally data sparse area the Faraulep AMOS provided needed observations of surface pressure, wind speed and direction which provided the ground truth for the satellite data. These AMOS data (Figure 3-02-3) reflected the change of Andy's track from the west to northwest at 171800Z. After the passage of a mid-latitude trough to the north of the system, the track returned to westward at 181200Z.

Following Andy's passage to the north of Faraulep and south of Guam, satellite fixes from 190530Z through 191730Z indicated it had ceased its westward movement and had

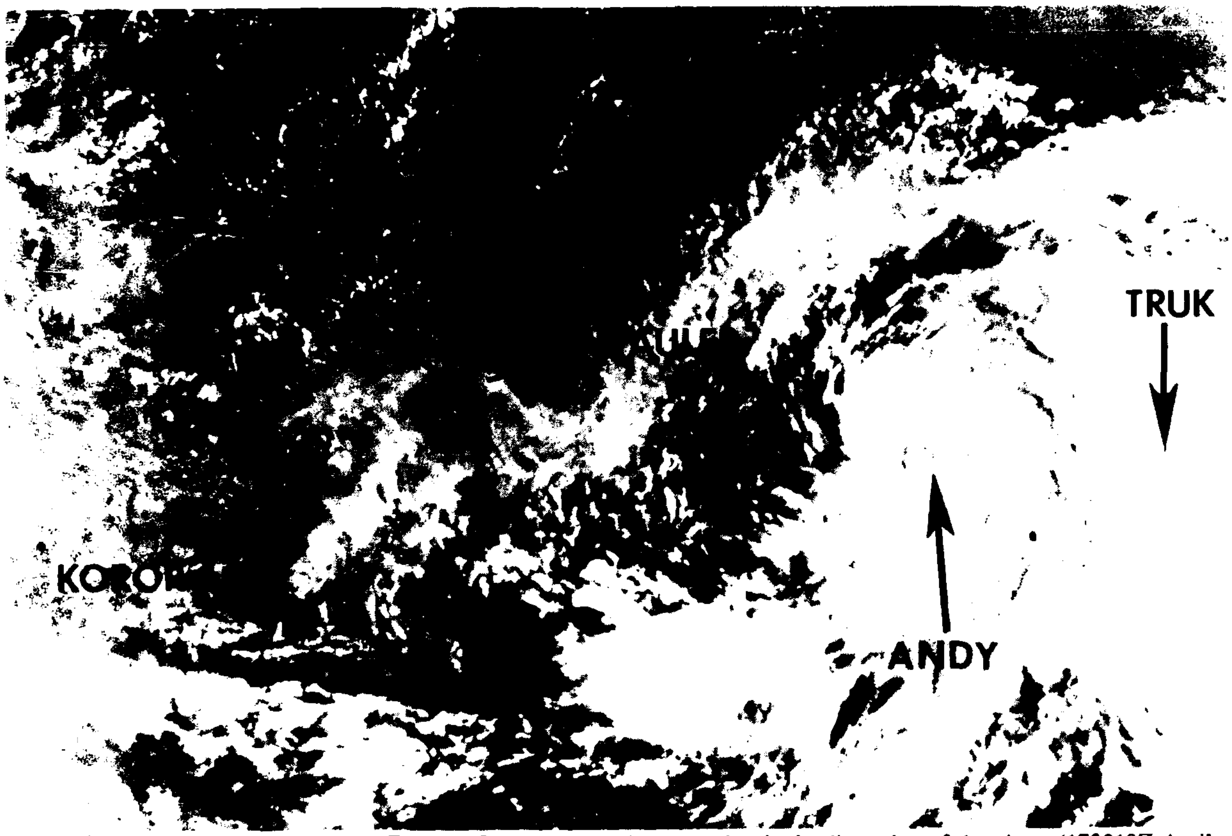


Figure 3-02-2. Andy bears down on Faraulep Island. Guam is just under the leading edge of the cirrus (172219Z April DMSP visual imagery).

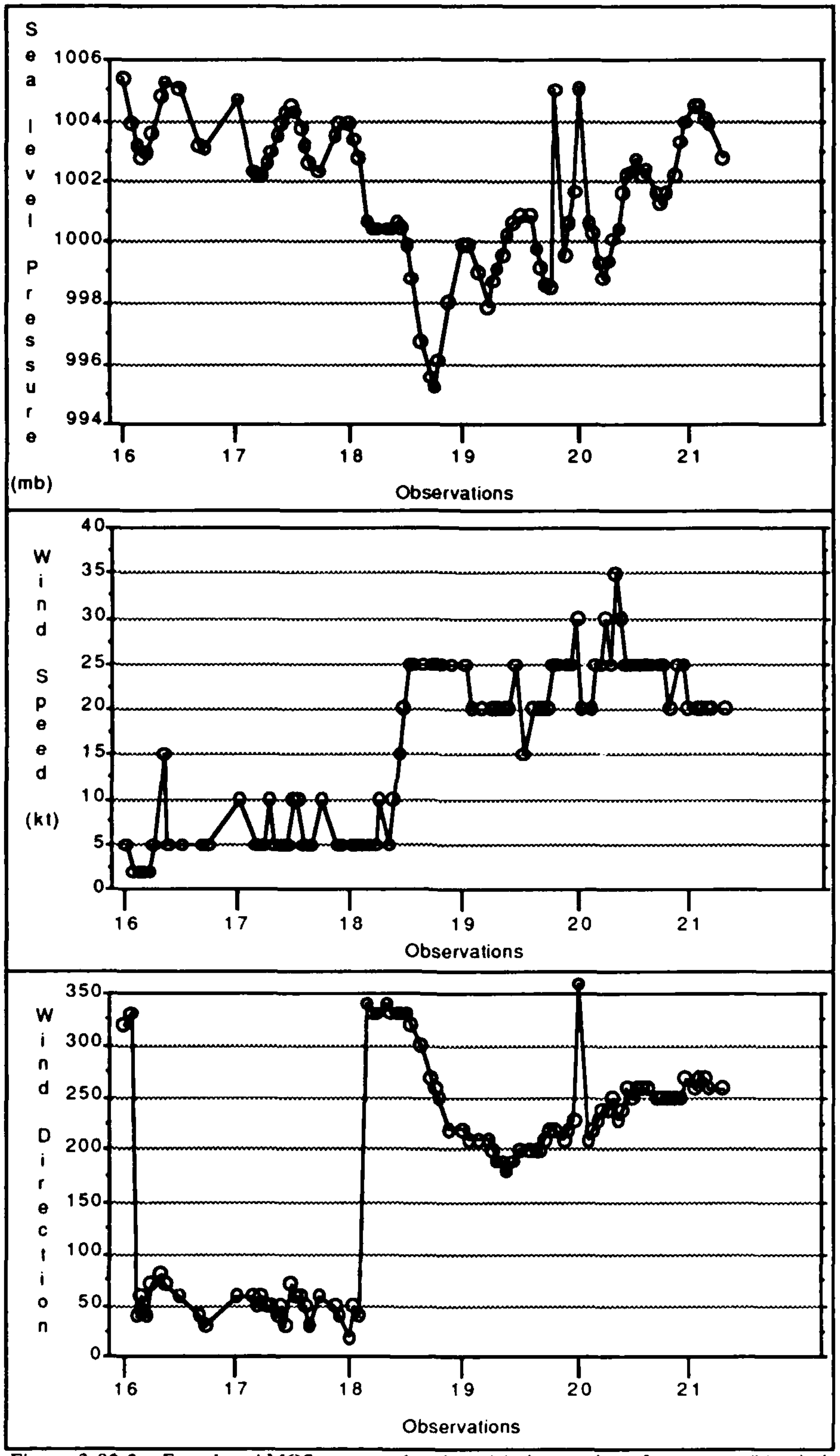


Figure 3-02-3. Faraulep AMOS reports showing: (a) time series of pressure, (b) wind speed and (c) wind direction. Andy's closest point of approach was at 181800Z. Note the major shift of wind direction and increase of wind speed preceded the lowest pressure.

begun to move to the north. Continued intensification (Figure 3-02-4) further aggravated the forecaster's dilemma. With recurvature possible as another mid-latitude trough moved eastward from Asia, there was an increasing threat to life and property in the Marianas. Until 200000Z, it appeared that the track would return to the west-northwest after a mid-latitude trough to the north progressed eastward and the lower tropospheric high pressure reestablished itself north of the cyclone. OTCM supported this synoptic assessment (Figure 3-02-5) in contrast to the climatological techniques, primarily CLIPER, which indicated a track to the north and just to the west of Guam. But Andy's continued slow northward movement required a reassessment of the synoptic situation. The track forecast was changed from west-northwestward to north, just west of Guam, followed by recurvature. The alternate forecast scenario became an early recurvature with passage southeast of Guam.

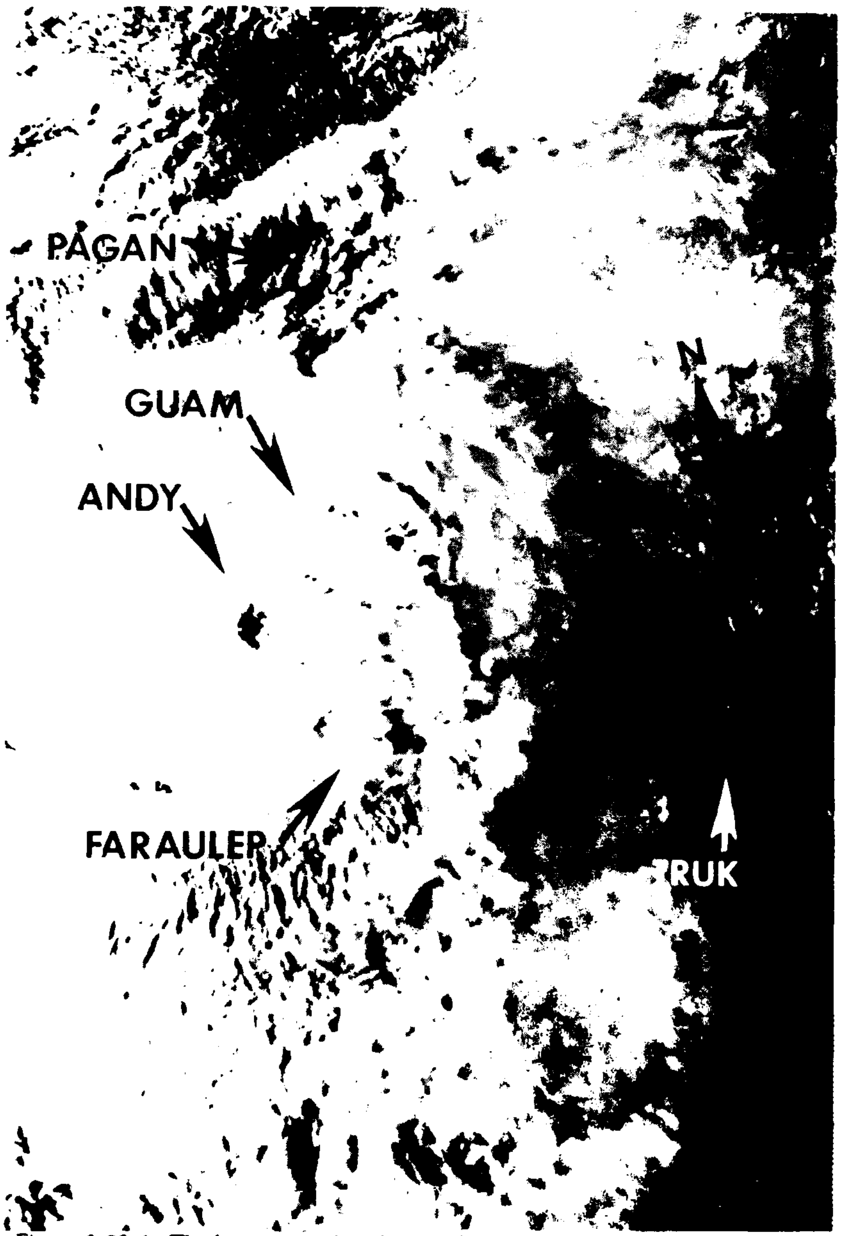


Figure 3-03-4. The low sun angle enhances the cloud top topography. Andy poses an imminent threat to the Marianas (210816Z April DMSP visual imagery).

The primary forecast held until 201700Z at which time it became apparent that recurvature had already taken place. A special tropical cyclone warning was issued with the updated forecast reflecting that Andy (Figure 3-02-6) would pass 45 nm (70 km) southeast of Guam.

Andy's closest point of approach (CPA) to Guam occurred at 202100Z 70 nm (130 km) to the southeast. The island was spared the intense maximum sustained winds near the center estimated to be 135-140 kt (69-72 m/sec). Sustained surface winds recorded on the island were 35-45 kt (18-23 m/sec) with peak gusts to 68 kt (35 m/sec). These resulted in crop damage, power outages and minor property damage, primarily due to fallen trees. In addition, torrential downpours caused localized flooding. At sea, the combat stores ship, **USS San Jose** came to the aid of a disabled fishing vessel in the path of the super typhoon.

After CPA, Andy continued to track northeastward and weaken as the vertical shear from the westerly winds aloft increased. Three days later, at 240000Z, when the central convection completely separated from the dissipating low-level circulation center (Figure 3-02-7), the final warning was issued.

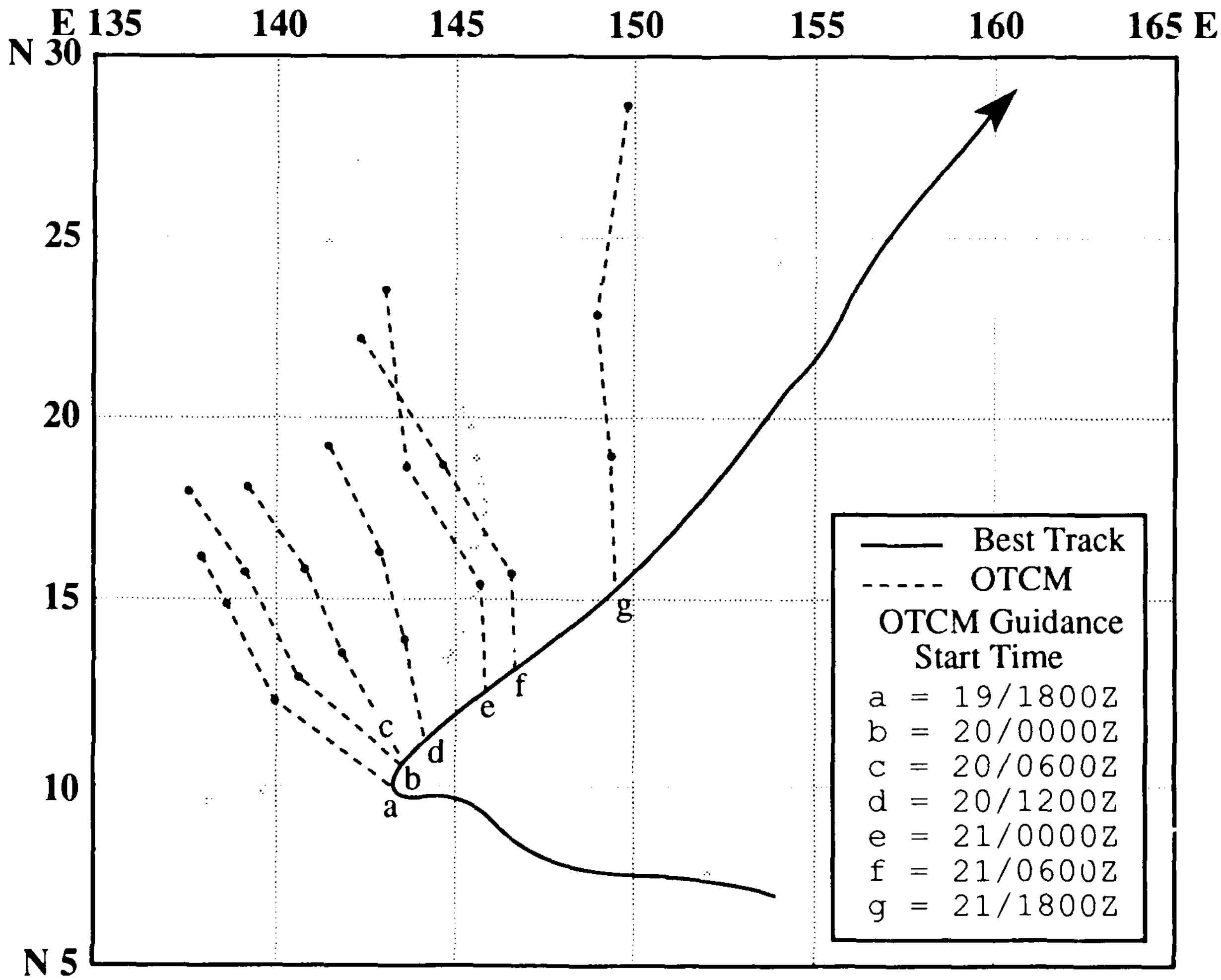


Figure 3-02-5. Comparison of OTCM guidance tracks from 191800Z through 211800Z with the final best track. After the start time for OTCM, the dots embedded in the dashed line indicate the location of the 24, 48 and 72 hour guidance.

Figure 3-02-6. Approaching super typhoon intensity, Andy is impressive on this matched pair of moonlit visual and enhanced infrared pictures (201202Z April DMSP visual and infrared imagery).

As a point of interest, Figure 3-02-8 is included to deomonstrate the value of multi-spectral imaging. In the visual image the low-level eye is completely obscured; however, a part of it can be seen in the enhanced infrared image.

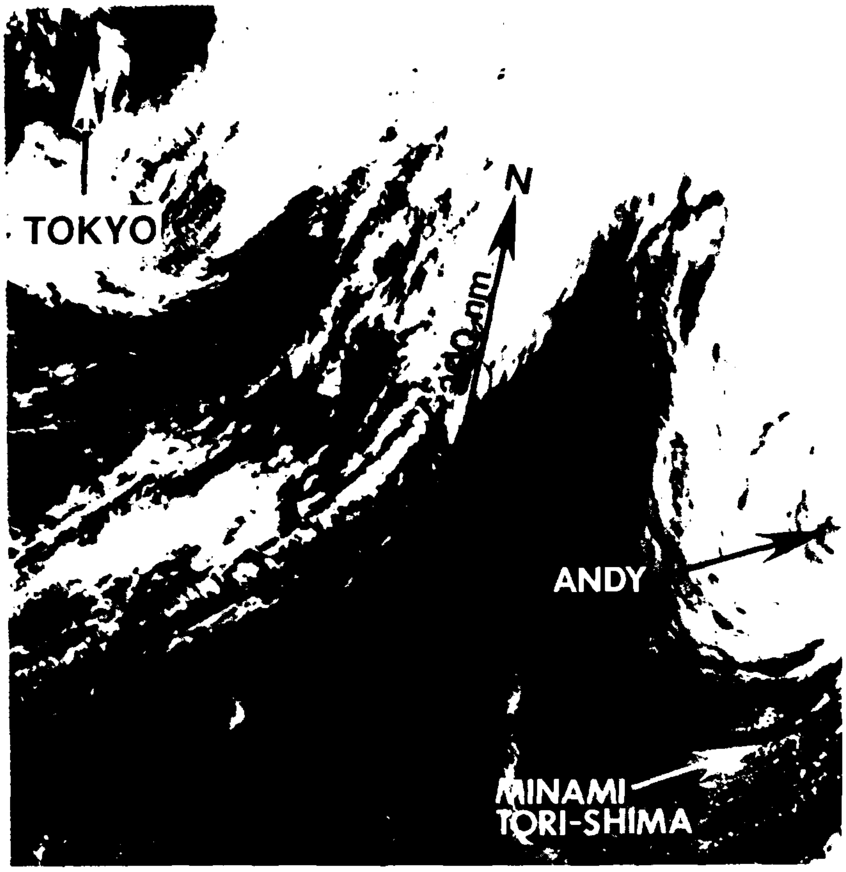


Figure 3-02-7. Remnants of Andy's low-level circulation (242322Z April DMSP visual imagery).

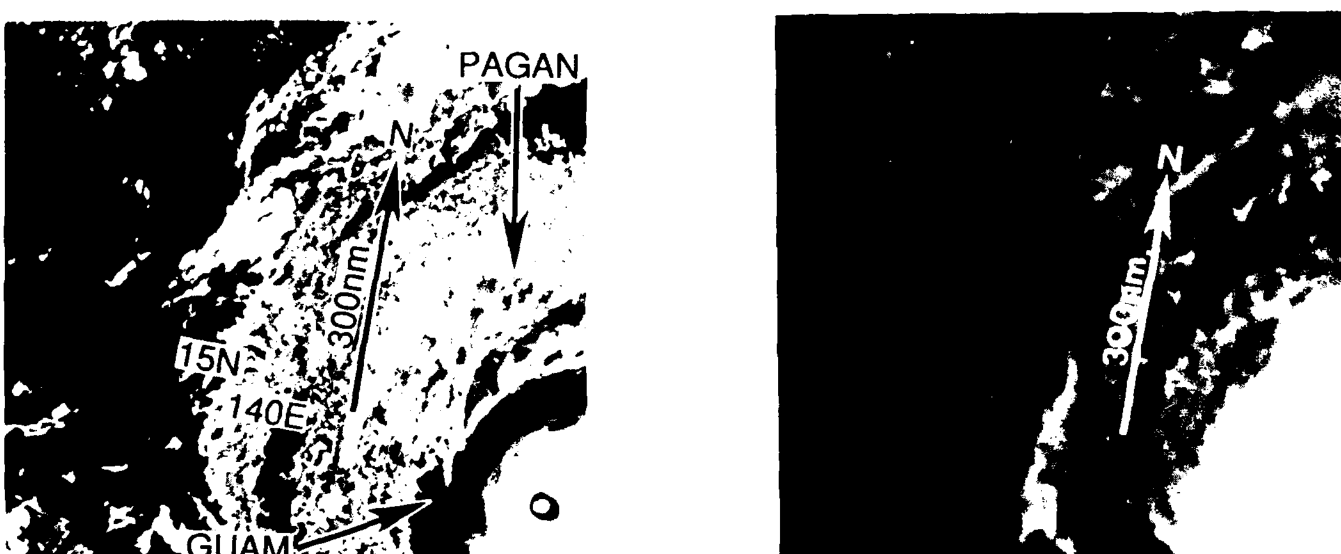
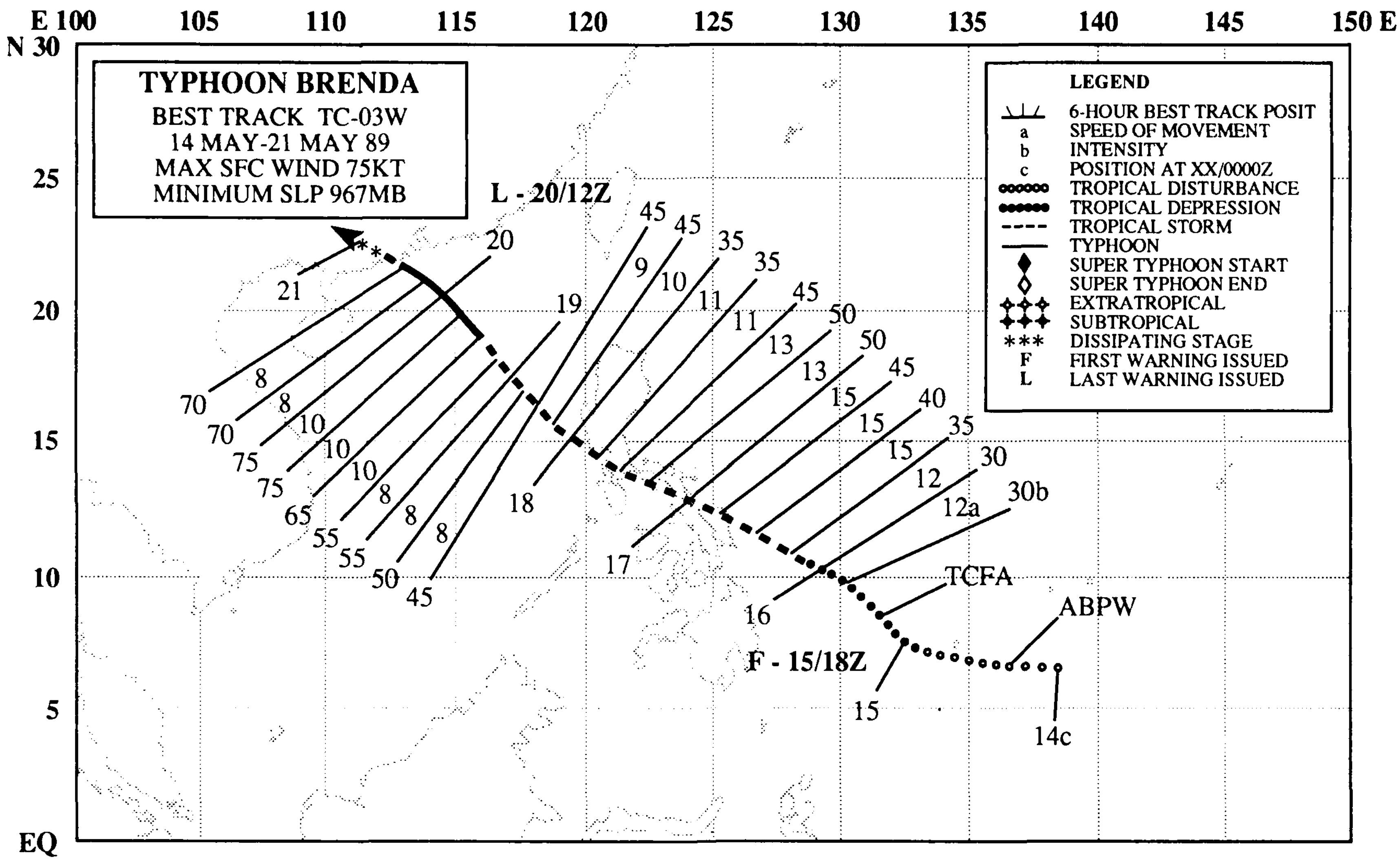


Figure 3-02-8. As Andy moves away from Guam, this picture pair shows the importance of multispectral since the eye is located at the extreme lower right edge of the polar orbiter image. Note a small portion of the low-level eye shows on the enhanced infrared (to the left). On the visual (to the right) the low-level eye is completely masked by the bright sunlight reflected from the eastern side of wall cloud (210434Z April NOAA visual and infrared imagery).


TYPHOON BRENDA
BEST TRACK TC-03W
14 MAY-21 MAY 89
MAX SFC WIND 75KT
MINIMUM SLP 967MB
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 20/12Z
F - 15/18Z
TCFA
ABPW
14c
E 100
105
110
115
120
125
130
135
140
145
150 E
N 30
25
20
15
10
5
EQ

TYPHOON BRENDA (03W)

The first of two typhoons to form in May, Brenda generated in the western Caroline Islands, moved northwestward across the central Philippine Islands, and then made landfall in China. It was the second of eleven tropical cyclones to cross the Philippines during the year.

After spawning Super Typhoon Andy in April, the tropics remained relatively quiet for two weeks. Then, on 14 May, the Significant Tropical Weather Advisory mentioned an area of broad convection with weak turning in the monsoon trough south of Yap. Continued organization of clouds and winds prompted the issuance of a Tropical Cyclone Formation Alert at 150730Z and the first warning at 151800Z. The system was upgraded to tropical storm at 160000Z.

Brenda (Figure 3-03-1) tracked across Samar and southern Luzon, exiting at the tip of the Bataan Peninsula. Closest point of approach to both NAS Cubi Point and Manila was 18 nm (35 km). Cubi Point's barograph recorded a minimum sea level pressure of 989 mb at 171800Z. To the north, Clark AB (WMO 98327) experienced maximum gusts of 38 kt (20 m/sec) and received minor damage. News reports indicated at least four water craft sank, and that more than 50 people were killed or missing in the Philippine Islands. In addition,

Figure 3-03-1. Brenda slams into the southern Luzon (170025Z May DMSP visual imagery).

thousands were left homeless, and communications and power were significantly disrupted.

Once in the South China Sea and again over warm water, Brenda (Figure 3-03-2) continued northwestward and intensified, reaching typhoon status at 191200Z. Meanwhile, the NOGAPs prognostic series forecast a mid-latitude short wave to move north of the tropical cyclone, indicating potential for recurvature. JTWC did forecast recurvature at 181200Z, based on an apparent northward motion of the circulation center on the nighttime infrared satellite imagery. Low confidence radar signatures also indicated a northward motion. Subsequent fixes based on visual imagery returned the cyclone's track to a northwestward direction. In turn, JTWC returned forecasts to a northwest motion and into the coast of China, west of Hong Kong.

Typhoon Brenda reached a maximum intensity of 75 kt (39 m/sec) at 191800Z before passing within 81 nm (150 km) of Hong Kong at 201200Z. The Royal Observatory at Hong

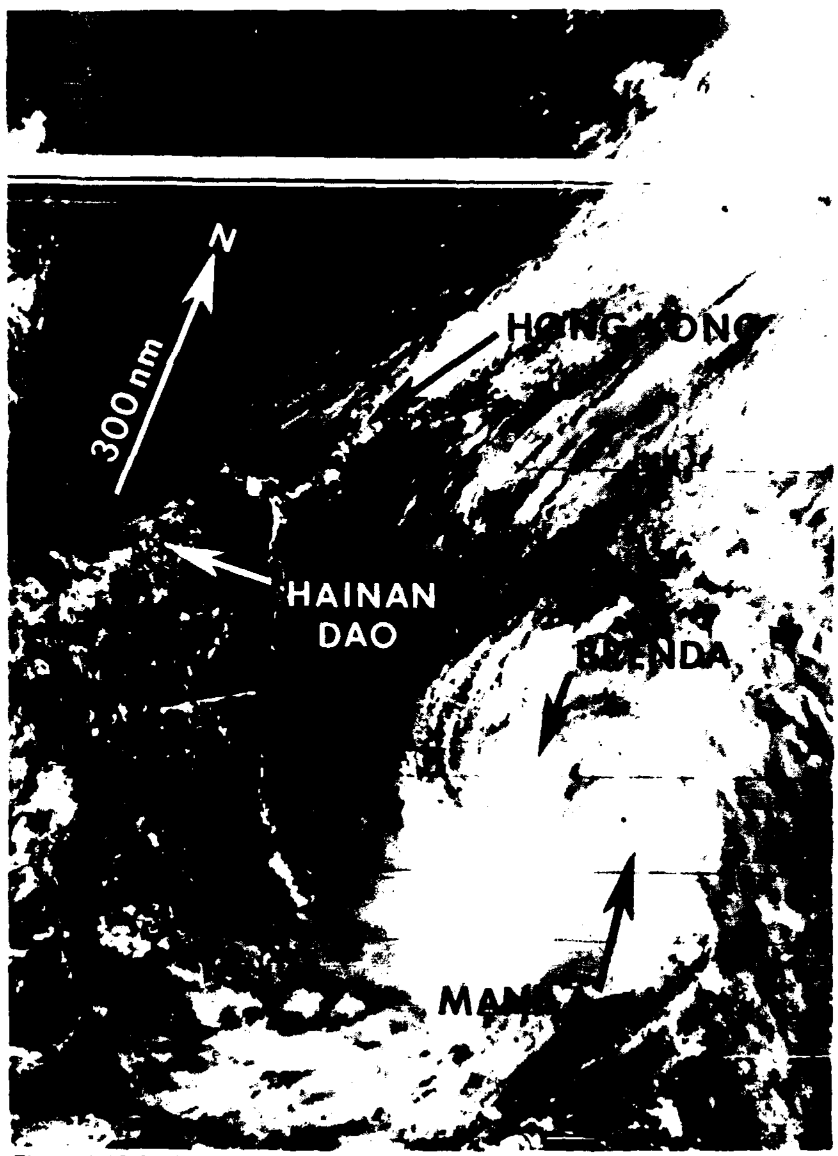


Figure 3-03-2. Moving over water, Brenda regains organization and reintensifies (180146Z May DMSP visual imagery).

Kong reported maximum gusts of 54 kt (28 m/sec), a minimum sea-level pressure of 995 mb and 17 inches (441 mm) of rain during the six days that Brenda and its enhanced southwest flow affected the area.

Brenda (Figure 3-03-3) made landfall on the south coast of China at 201400Z and dissipated over land in the Guangdong Province. Preliminary reports indicated that at least 84 people perished in southern China, and that widespread flooding due to the heavy rains damaged about 3.5 million acres (1.4 million hectares) of land. In Hong Kong six people were killed, one was missing, and the heavy rains resulted in landslides, floods and large losses in livestock and fish farming.

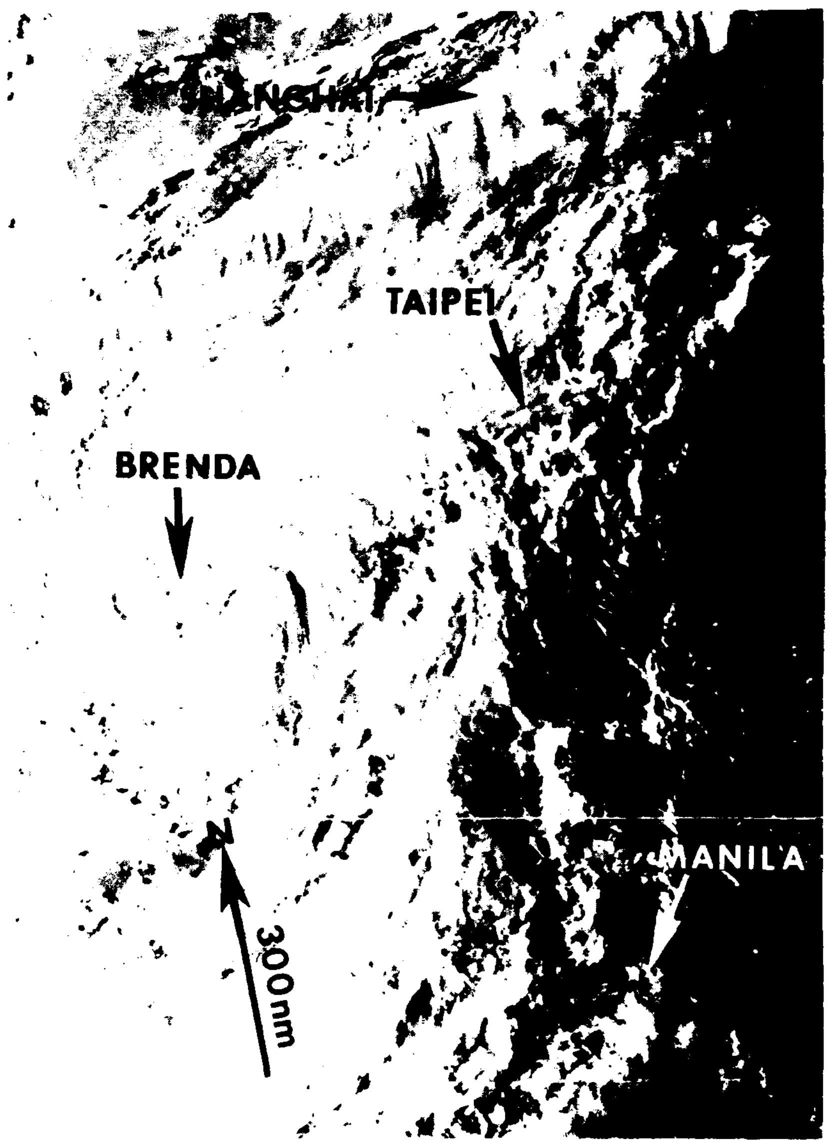
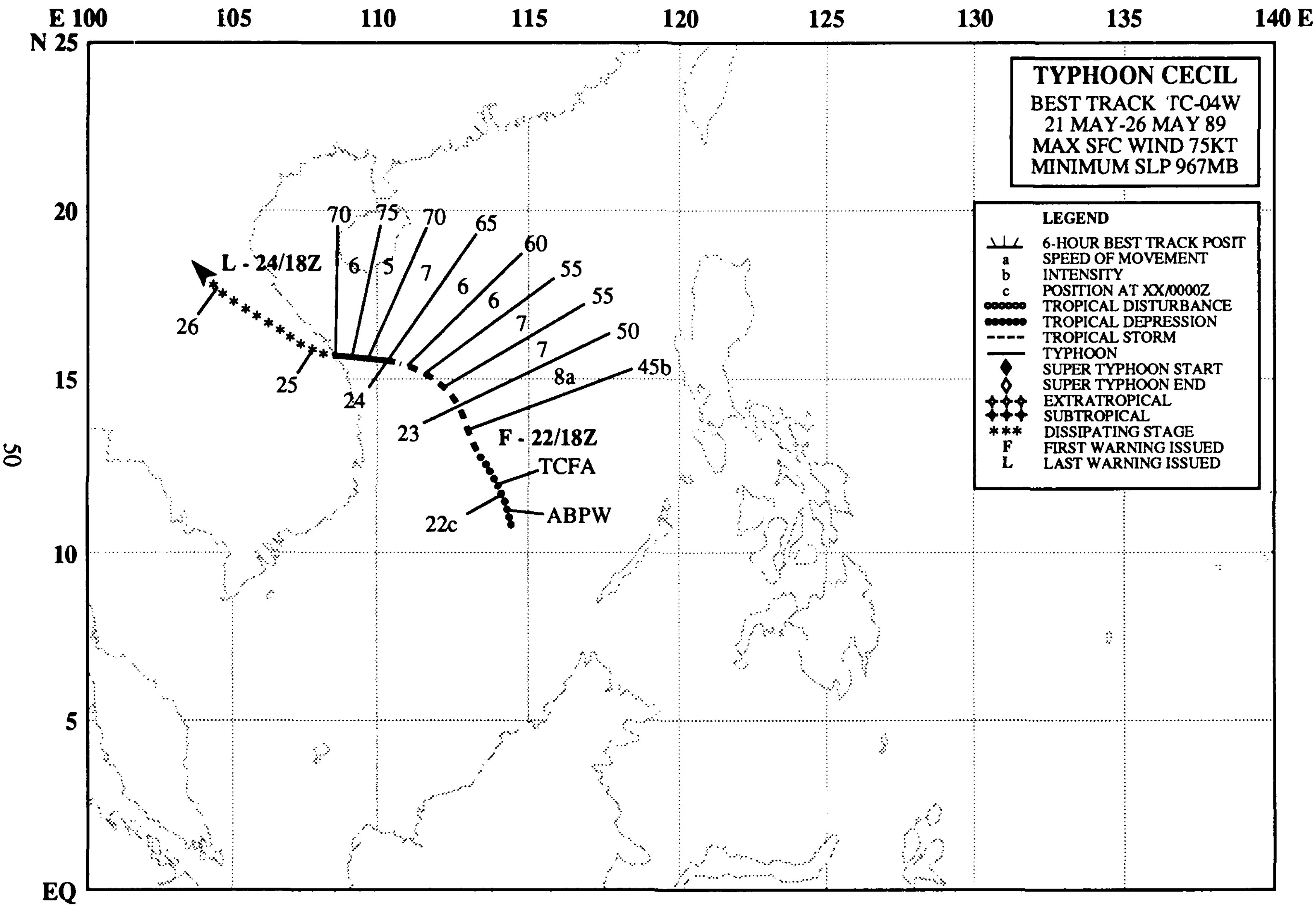


Figure 3-03-3. This brightly lit low sun angle photo shows Brenda's convective spirals as the typhoon approaches the coast. The sun is low to the west, and its rays scatter forward, through the aerosols, and out to space. The gray, milky-looking areas around the periphery of Brenda reveal the presence of aerosols in the lower layer of the atmosphere that are being trapped, and concentrated, as a the result of subsidence (201021Z DMSP visual imagery).


TYPHOON CECIL
BEST TRACK TC-04W
21 MAY-26 MAY 89
MAX SFC WIND 75KT
MINIMUM SLP 967MB
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 100
105
110
115
120
125
130
135
140 E
N 25
20
15
10
5
EQ
L - 24/18Z
F - 22/18Z
TCFA
ABPW
70
75
70
65
60
55
55
50
45b
6
5
7
6
6
7
7
8a
26
25
24
23
22c

TYPHOON CECIL (04W)

The second of two typhoons during the month of May, Cecil developed in the South China Sea in the wake of Typhoon Brenda (03W).

On 20 May, an extensive monsoon trough spread across the Bay of Bengal into the South China Sea where it terminated in Typhoon Brenda (03W). As Brenda moved northwestward and dissipated over southern China, it left behind an area of enhanced low-level southwesterly flow. Additionally, the dissipation of Brenda (03W) reduced the vertical wind shear from the north over the genesis area for Cecil. Cecil was first detected on 21 May as a low-level cyclonic circulation associated with the enhanced southwesterly flow. The Significant Tropical Weather Advisory was reissued at 212000Z to cover this circulation and its persistent cloudiness. When surface synoptic reports and additional satellite data indicated that the system was becoming better organized, a Tropical Cyclone Formation Alert was issued at 220230Z.

Initially, the deep convection was only located in the southern semicircle, but on 22 May the convection wrapped around the circulation center. This event, along with falling central pressures precipitated the first warning on Tropical Depression 04W at 221800Z. The warning was then amended based on subsequent synoptic reports, and the system upgraded to a tropical storm.

At the start, Cecil was forecast to track northward through the weakness in the subtropical ridge created by Brenda (03W). This forecast was supported by guidance from the dynamic aid, OTCM, and HPAC, an aid which blends one half persistence with one half climatology. But, the tropical cyclone turned towards the west on 23 May and tracked into central Vietnam in response to ridging to the north over China.

With inflow from the extensive low-level southwest monsoonal flow, divergence aloft and weak vertical wind shear, Cecil reached typhoon intensity at 240000Z (Figure 3-04-1). The typhoon tracked across the coast of Vietnam at 241800Z with maximum sustained surface winds estimated at 70 kt (35 m/sec). News agencies reported that at least 52 people perished, 37 were injured, over 100,000 were left homeless and 700 water craft were destroyed. Persistent convection associated with Cecil produced heavy rains inland which resulted in flooding and crop damage in Laos and northeastern Thailand.

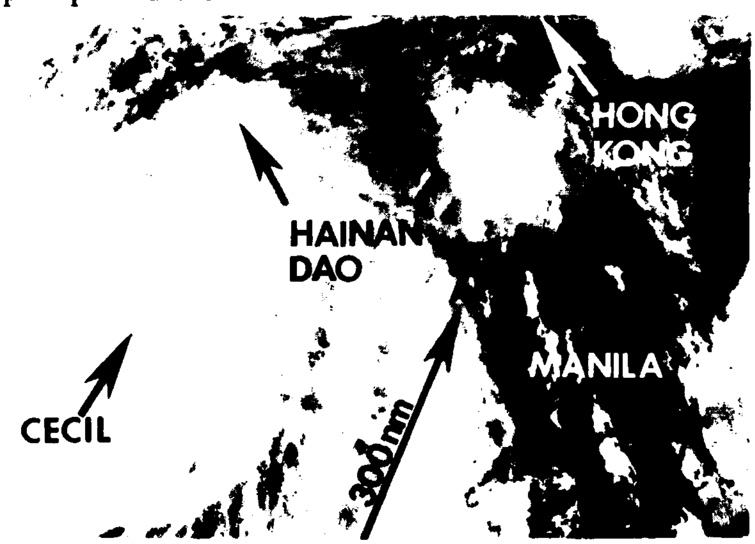
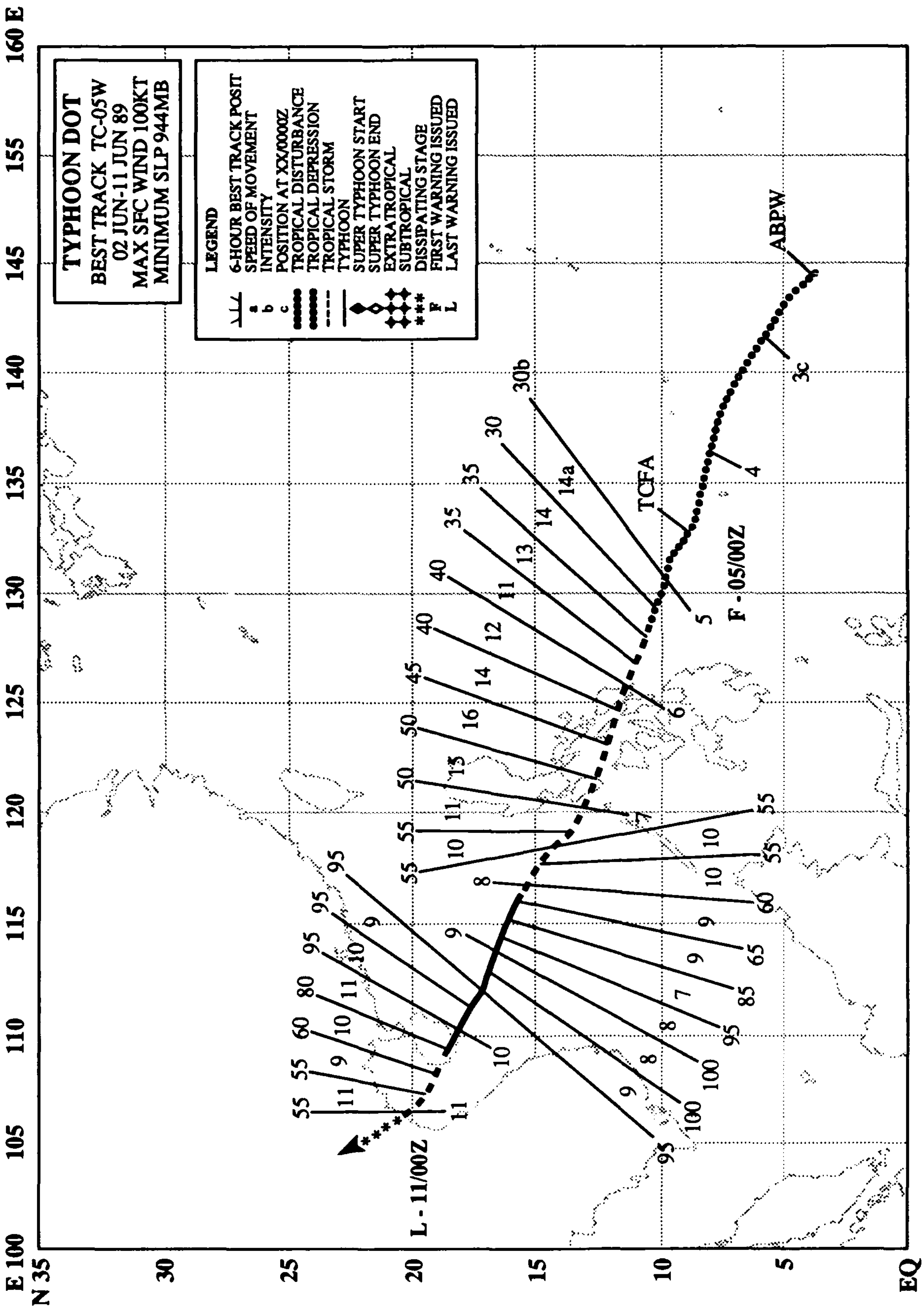


Figure 3-04-1. Cecil with a large ragged 40 nm (75 km) diameter eye approaches the coast of Vietnam (240539Z May NOAA visual imagery.)


TYPHOON DOT
BEST TRACK TC-05W
02 JUN-11 JUN 89
MAX SFC WIND 100KT
MINIMUM SLP 944MB
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
ABPW
TCFA
F - 05/00Z
L - 11/00Z
E 100
105
110
115
120
125
130
135
140
145
155
160 E
N 35
30
25
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EQ

TYPHOON DOT (05W)

Dot, the first of two significant tropical cyclones in June, formed in low latitudes south of the central Caroline islands, moved steadily west-northwestward and crossed the Philippine Islands. It reached typhoon intensity in the South China Sea and eventually dissipated over northern Vietnam.

After Cecil (04W) tracked across the South China Sea and into Vietnam the last week of May , the tropics were relatively quiet. Then light westerly surface winds appeared in the southern Philippine Sea and cloudiness increased. In this zone of maximum cloudiness on 2 June Dot, as a tropical disturbance, was identified and noted in the Significant Tropical Weather Advisory as having fair potential for development. On 4 June the disturbance passed north of the island of Palau in the western Carolines and became better organized, which prompted a Tropical Cyclone Formation Alert at 041230Z. A further increase in convection and organization led to the first warning at 050000Z when the system was approximately 300 nm (555 km) southwest of the island of Samar in the Republic of the Philippines.

Tropical Depression 05W was upgraded to Tropical Storm Dot (Figure 3-05-1) at 051200Z, twelve hours before making

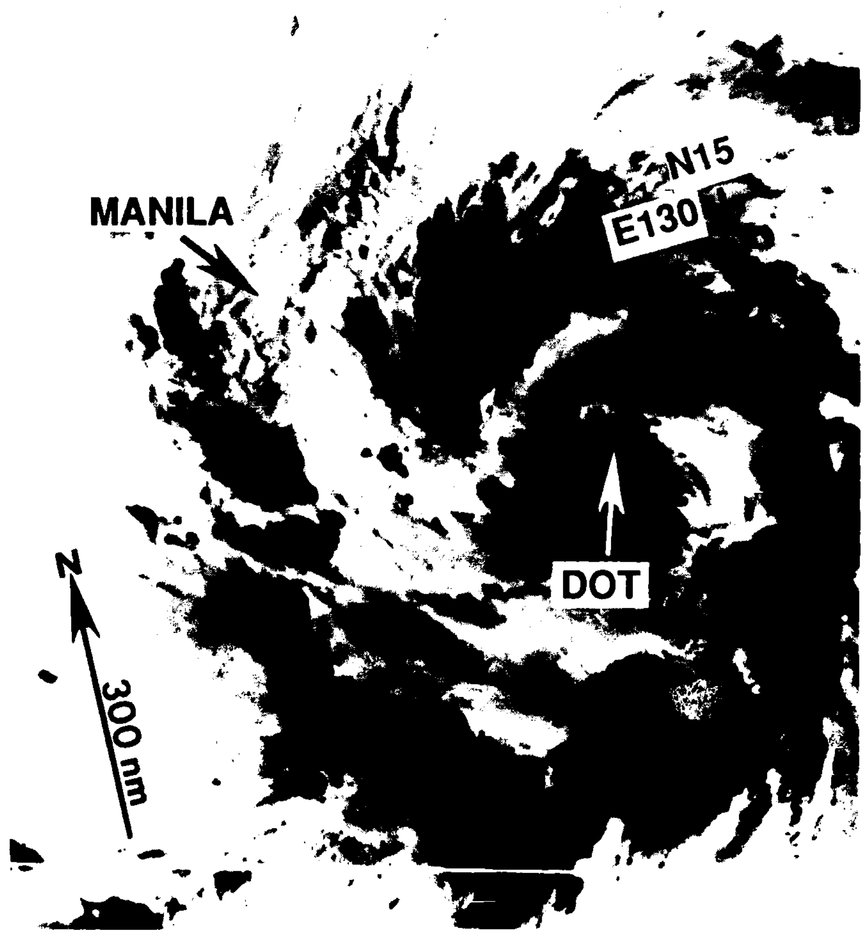


Figure 3-05-1. As Dot reaches tropical storm intensity, it's central dense overcast and surrounding band of convection blanket a large portion of the Philippine Sea (051801Z June NOAA infrared imagery).

landfall on Samar. Dot accelerated slightly while crossing the central Philippine Islands which was in agreement with the results of Sikora's (1976) movement study. The open waters of the Sibuyan Sea and the relatively low relief of the adjacent islands allowed the circulation aloft to intensify slowly, but the rugged topography limited the surface effects. Clark Air Base's radar (WMO 98327) located the circulation center at 061835Z over south central Mindoro. As suspected from the previous satellite imagery, the analysis of surface pressure reports from land stations revealed the system's large size (Figure 3-05-2).

Upon entering the South China Sea, Dot initially took a more northward track. This increase in northward component, coupled with the approaching frontal system and the guidance of most of JTWC's objective aids, led JTWC to forecast Dot's track to the east and north of Hainan Island (Figure 3-05-3). However, the tropical cyclone never linked up with the approaching frontal system and continued west-northwestward. Weak vertical wind shear and the warm waters of the South China Sea allowed Dot to reach typhoon intensity. Peaking at an intensity of 100 kt (51 m/sec) on 9 June (Figure 3-05-4), the typhoon then weakened as it approached and crossed southern Hainan Island. Dot crossed the Gulf of Tonkin as a tropical storm and made landfall near Haiphong, Vietnam at 110600Z. It dissipated six hours later in the mountains northwest of Hanoi.

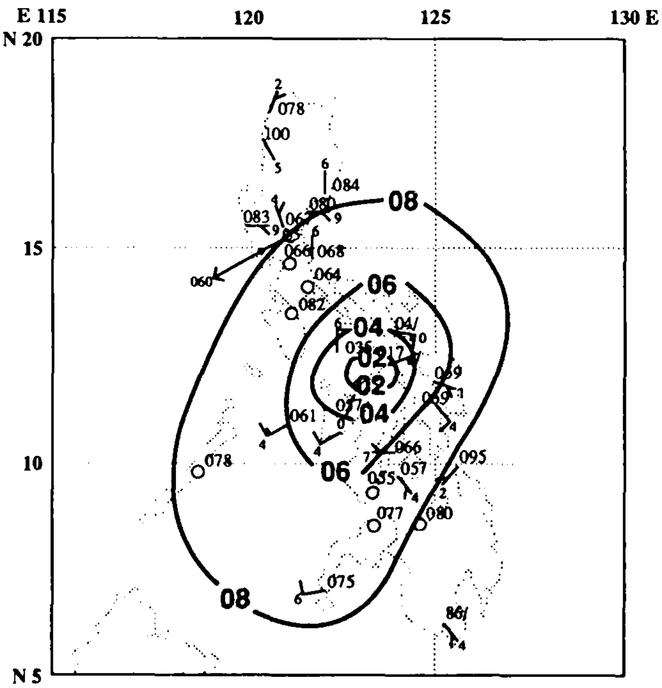


Figure 3-05-2. Based on the surface wind and pressure plots for 061200Z, the isobaric analysis shows the large size of the circulation.

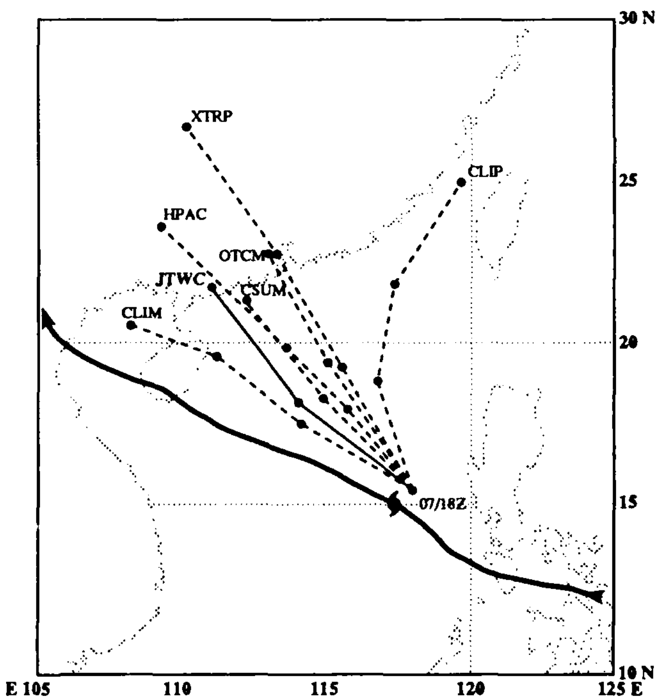


Figure 3-05-3. Objective guidance and the forecast from 071800Z through 24, 48 and 72 hours. Note: the displacement of the 071800Z starting point to the north of the best track. This is the result of adjustment to the best track caused by later data.

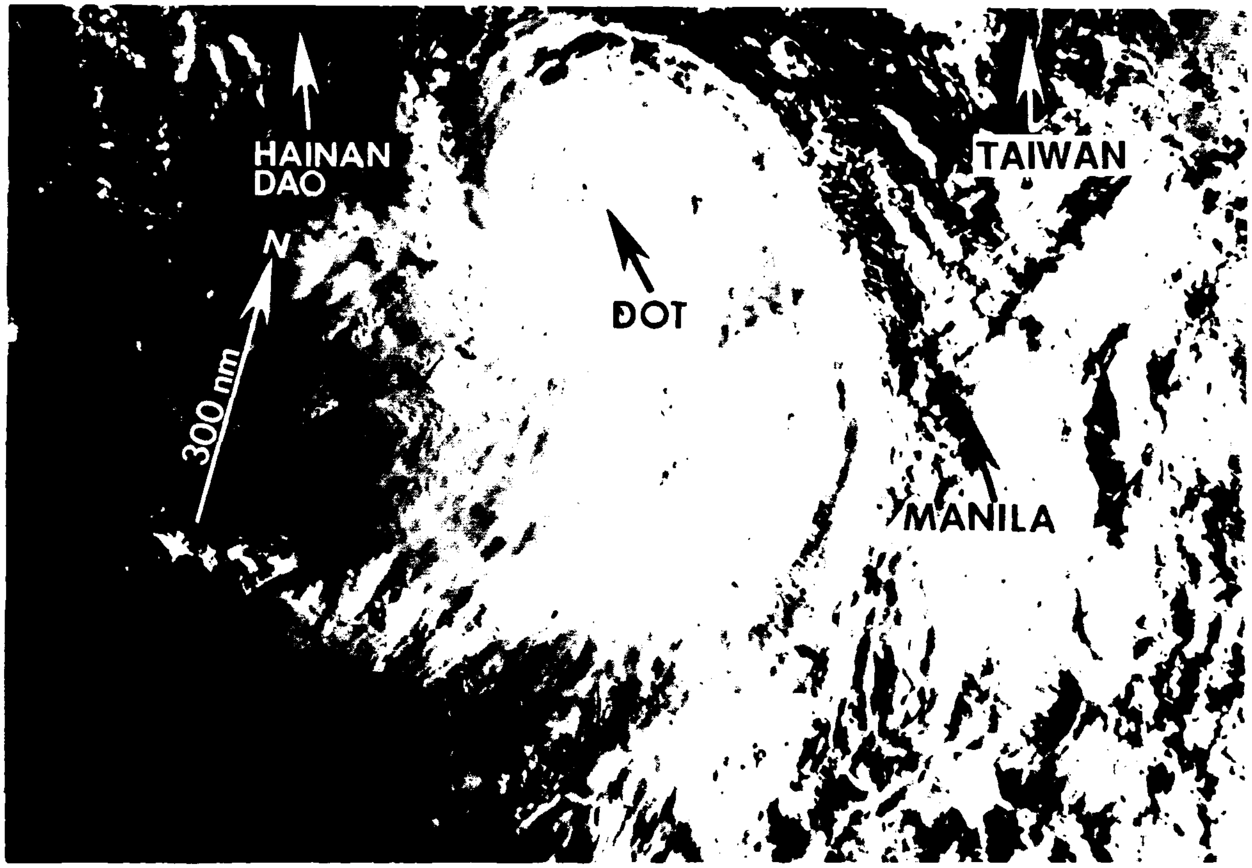
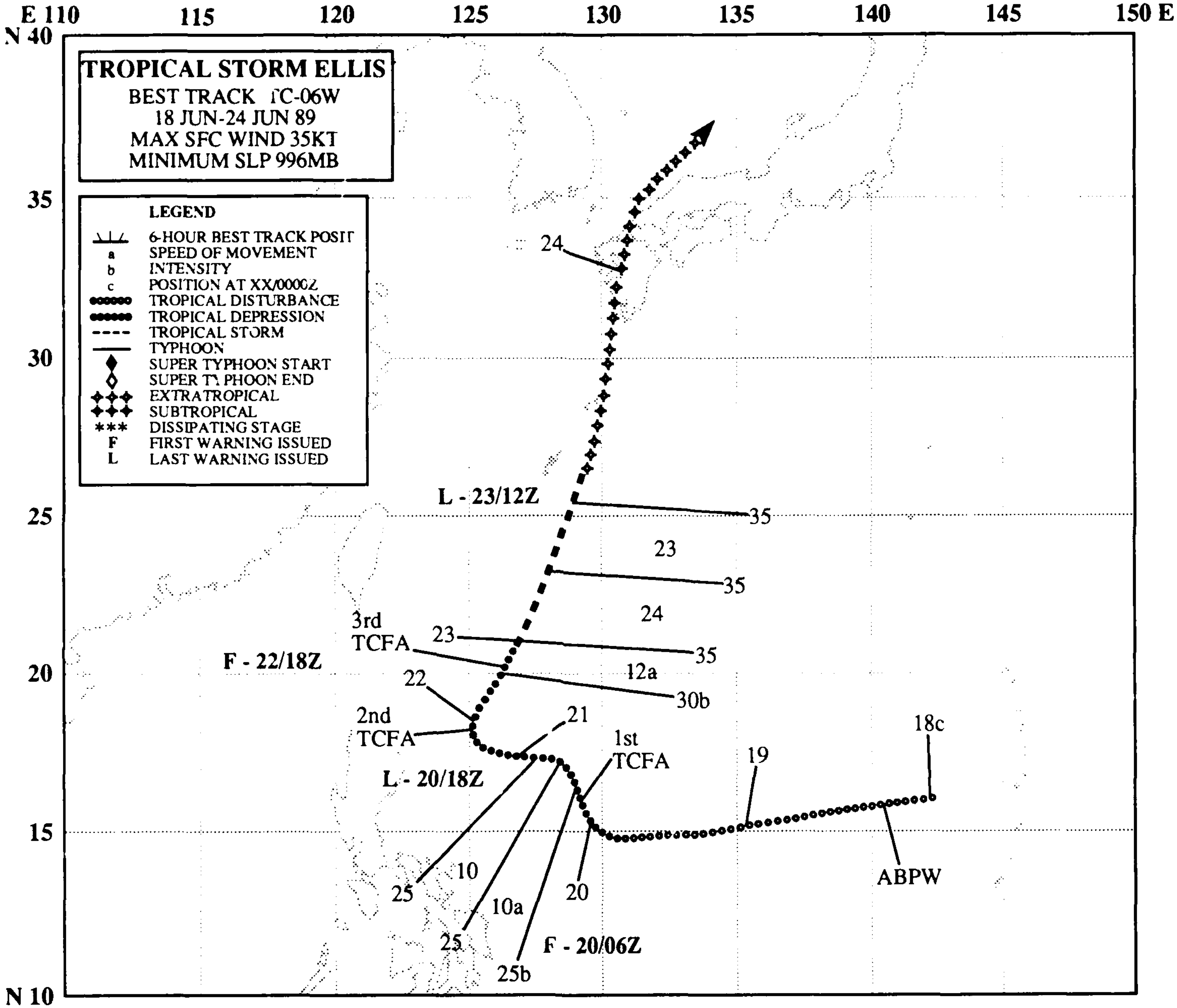


Figure 3-05-4. Nearing peak intensity, Typhoon Dot tracks towards Hainan Island (082225Z June DMSP visual imagery).


TROPICAL STORM ELLIS
BEST TRACK TC-06W
18 JUN-24 JUN 89
MAX SFC WIND 35KT
MINIMUM SLP 996MB
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 110
115
120
125
130
135
140
145
150 E
N 40
35
30
25
20
15
N 10
L - 23/12Z
F - 22/18Z
L - 20/18Z
F - 20/06Z
3rd
TCFA
2nd
TCFA
1st
TCFA
ABPW
18c
19
20
21
22
23
24
35
12a
30b
10
10a
25
25b

TROPICAL STORM ELLIS (06W)

The second of two tropical cyclones to form in June, Ellis interrupted the series of "straight runners" that occurred from Typhoon Brenda (03W) through Typhoon Dot (05W). After five days as a poorly defined system, Ellis briefly peaked at tropical storm intensity before becoming extratropical and making landfall in Japan. (This tropical cyclone provided the first opportunity for JTWC to use the newly instituted Tropical Depression Warning format as stated in a change to USCINCPACINST 3140.1T. This change addressed warnings when the depression was not expected to reach tropical storm intensity. These warnings were to be issued every twelve hours instead of every six hours as is the case for Tropical Cyclone Warnings.)

On 18 June, a disturbance formed in the Philippine Sea 210 nm (390 km) northwest of Guam and was mentioned on the Significant Tropical Weather Advisory. The disturbance was classified as having poor potential for further development, due to the lack of favorable upper-level support. It appeared that the proximity of the TUTT to the north through northeast restricted the outflow from the convection. However, the next Advisory was reissued at 192100Z to upgrade the potential for further development to fair after the central convection flared at the morning convective maximum and synoptic data revealed the development of the low level cyclonic circulation. A Tropical Cyclone Formation Alert followed at 200430Z when the deep convection had persisted. Within ninety minutes, the first Tropical Depression Warning was issued. The application of the Tropical Depression Warning was appropriate since this depression (Figure 3-06-1) appeared deeply embedded in the monsoon trough and further development was unlikely. At 201800Z, the second, and final, Tropical Depression Warning followed as the poorly defined cloud system weakened 450 nm (835 km) east of Luzon.

As the disturbance moved westward toward Luzon, the 200 mb pattern underwent a substantial change. On 18 June, a narrow ridge aloft with an east to west orientation extended through the Bonin Islands (south of Japan). Simultaneously, a weak trough existed across Korea and western Honshu. Short waves exiting China deepened this trough until it extended southward from the Yellow Sea to Taiwan. The rawinsonde data from Okinawa (WMO 47936) showed 60-meter height falls at 200 mb from 19 to 20 June. This adjustment of the upper-level pattern favorably positioned divergence over the remnants of the tropical depression.

With synoptic data indicating minimum sea-level pressures near 1001 mb, the next convective flare up prompted a second Alert at 211900Z. Then, with the synoptic situation unchanged, a third Alert followed 24 hours later. This Alert addressed the fact that the maximum winds were displaced 180 nm (335 km) east of the system's center. This asymmetric displacement of a broad area of gales away and to the east of the low-level circulation center was unusual and accompanied Ellis for the remainder of its lifetime. At 222100Z, JTWC issued the first Tropical Cyclone Warning on Tropical Depression 06W (Figure 3-06-2). The system was forecast to move slowly toward the northeast, steered by the southwesterly flow ahead of the trough. Further, it would only reach minimal tropical storm intensity before encountering increased vertical wind shear and cooler air behind a stationary front. The front had pushed south of Okinawa during the preceding three days.

While the intensity was correctly forecast, Tropical Storm Ellis led JTWC on a high speed chase, doubling its forward speed from 12 to 24 kt (6 to 12 m/sec) as it sped toward Okinawa. By the fourth warning at 231200Z, Ellis was becoming extratropical, having linked with the previously mentioned stationary front; but it was not weakening. The

system passed 90 nm (165 km) east of Kadena AB. Kadena (WMO 97931) provided two radar fixes on Ellis, as it passed by, and reported peak gusts to 22 kt (11 m/sec). The system passed over Kyushu and extreme western Honshu before dissipating over the Sea of Japan on 24 June. Although gales persisted as Ellis continued northward, no reports of major damage or fatalities were received.

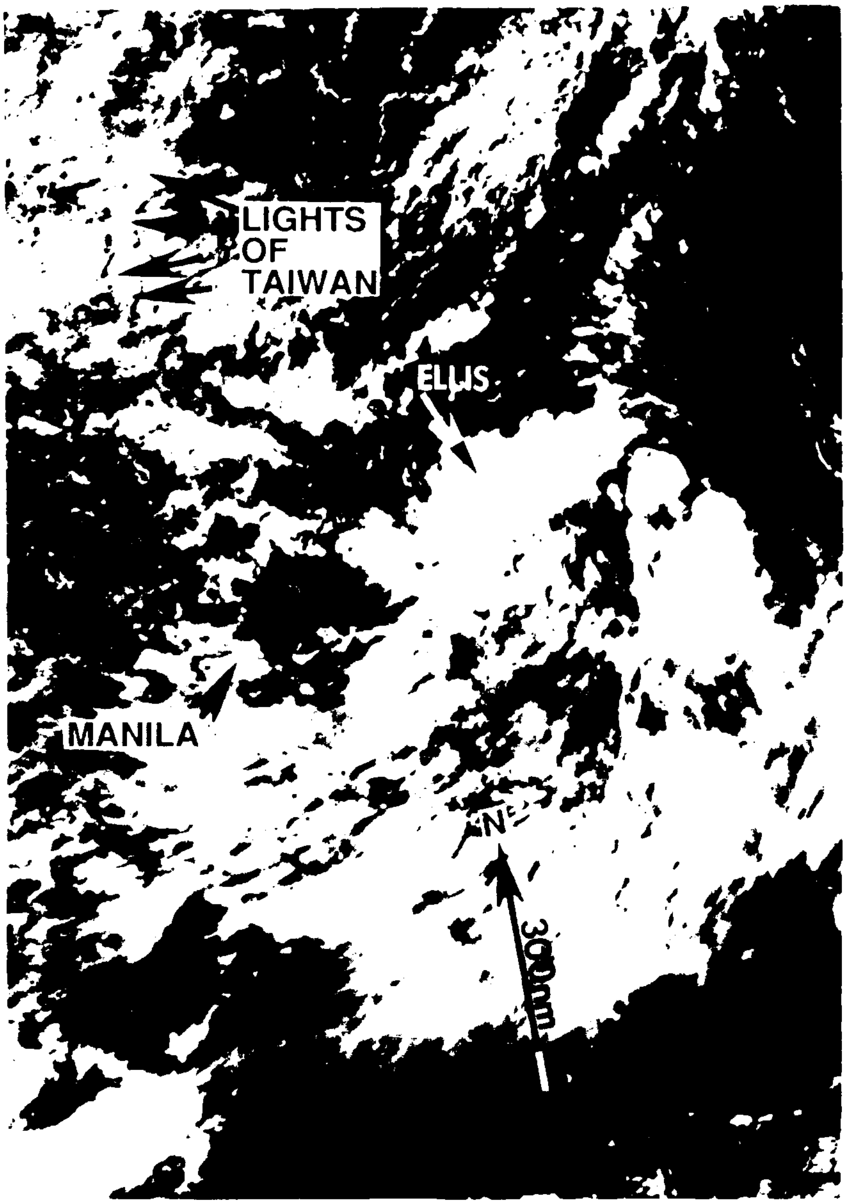
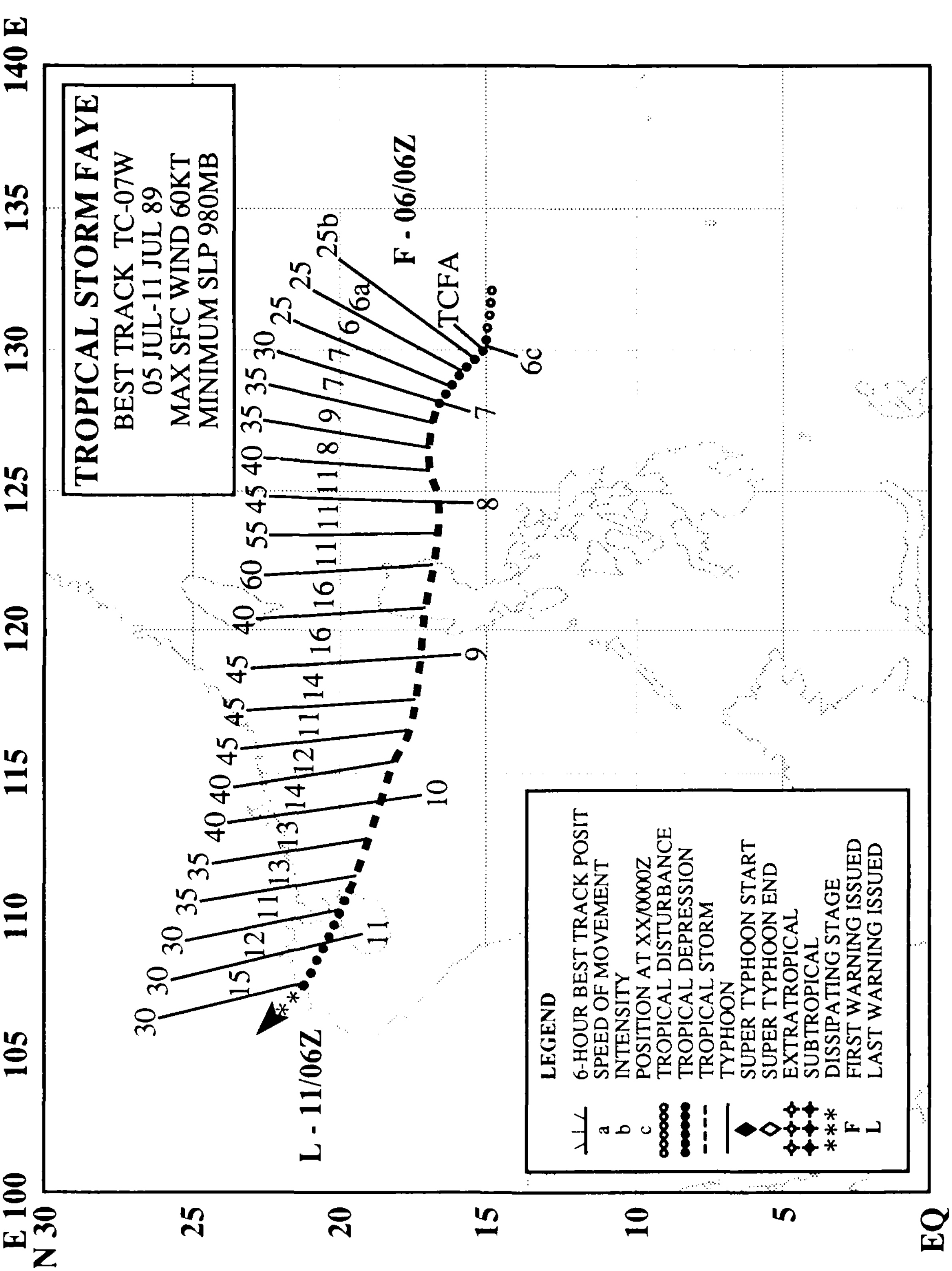


Figure 3-06-1. Nighttime visual picture of the disorganized cloud signature of the tropical depression after the first warning. Bright moonlight makes the image look like daytime. Note the city lights of Taiwan (201327Z June DMSP visual imagery).

Figure 3-06-2. Ellis starts moving northward towards Okinawa (222106Z June DMSP visual imagery).



TROPICAL STORM FAYE
BEST TRACK TC-07W
05 JUL-11 JUL 89
MAX SFC WIND 60KT
MINIMUM SLP 980MB
F - 06/06Z
L - 11/06Z
TCFA
LEGEND
a 6-HOUR BEST TRACK POSIT
b SPEED OF MOVEMENT
c INTENSITY
POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 100
105
110
115
120
125
130
135
140 E
N 30
25
20
15
10
5
EQ

TROPICAL STORM FAYE (07W)

After a two-week break in activity, Faye was the first of seven tropical cyclones to form in July. It formed in the monsoon trough and intensified at a normal rate as it tracked west-northwestward towards the Philippines. Faye weakened as it crossed north-central Luzon and reintensified slightly in the South China Sea. It weakened again in the central South China Sea, and crossed the island of Hainan before making landfall on the coast of northern Vietnam.

On 4 July, a surge in the southwest monsoon caused a widespread increase of convective activity in an area west of the Mariana Islands. This convection was short-lived — peaking at 050000Z and dissipating for the most part by 051200Z. Out of the remnants of this convection arose a small area of deep convection near 15° north latitude and 130° east longitude. This deep convection continued to develop after the early morning convective maximum, and at 060200Z a Tropical Cyclone Formation Alert was issued on the disturbance. The first tropical cyclone warning on Tropical Depression 07W followed at 060600Z. At that time, the depression had a partially exposed low-level circulation to the north of the deep convection with restricted upper-level outflow in the northern semicircle. This displacement of convection introduced some uncertainty in the location of the low-level circulation center (Figure 3-07-1) until first light the next day.

A short wave trough passing to the north induced a small northward shift in track during the first 24 hours in warning. As the short wave trough moved eastward, the subtropical ridge strengthened to its west and the depression began moving to the west. Continued development resulted in an upgrade to tropical

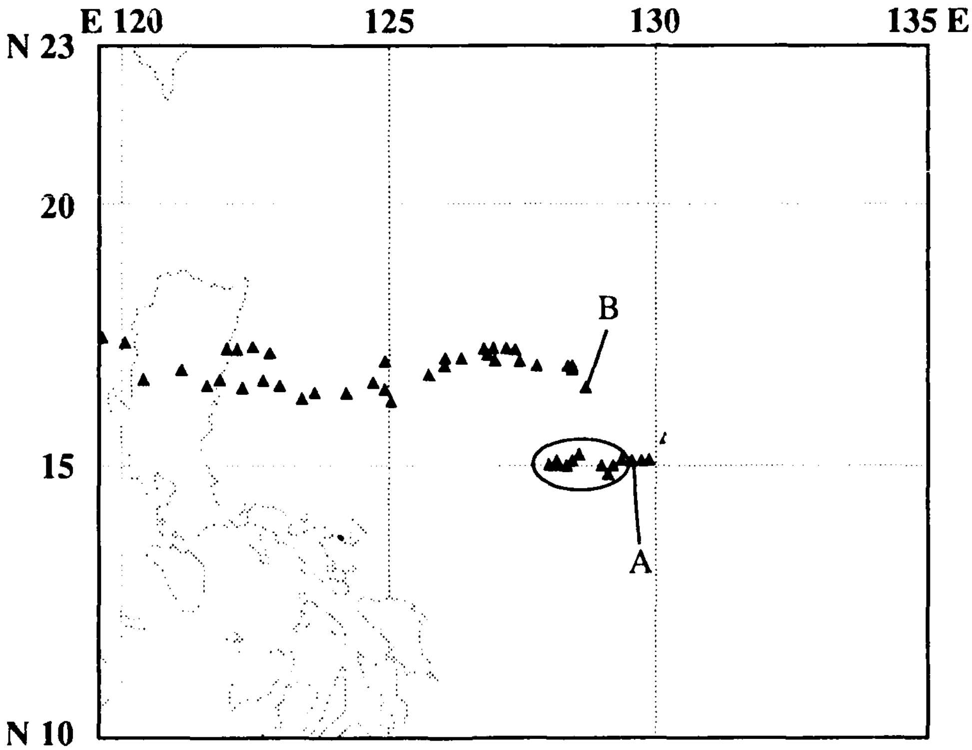


Figure 3-07-1. After the last visual fix at 060730Z (point A), plots of satellite fixes (encircled) through the night show that cold cloud top targets on the infrared imagery can be misleading. The visual data the next day at 062330Z (point B) enabled the forecaster to get the weak circulation back on track.

storm intensity at 070600Z. Throughout the next 24 hours, the subtropical ridge remained unchanged and Faye tracked westward and intensified.

Tropical Storm Faye reached its peak intensity of 60 kt (31 m/sec) at 081200Z, just prior to making landfall in north-central Luzon. Remarks from the radar site at Baguio (WMO 98321) about the change of wind direction from northwest to southwest and 35 kt (18 m/sec) gusts proved invaluable in tracking Faye as it accelerated over Luzon and retained tropical storm intensity as it entered the warm waters of the South China Sea late on 8 July. Moving out into open waters, it began to reintensify. In the central South China Sea, Faye moved into an environment of strong upper-level northeasterlies which began to shear the system. Despite this strong shear, Faye (Figure 3-07-2) retained much of its convective organization and its tropical storm intensity until it reached the island of Hainan.

Late on the 10 July, Faye crossed northern Hainan causing telecommunication interruptions and the destruction of pepper, sugar cane and coffee crops. It was downgraded to a tropical depression as it entered the Gulf of Tonkin. The low-level circulation, which was displaced 45 nm (85 km) from the deep convection, made landfall near Haiphong, Vietnam at 110600Z and quickly dissipated.

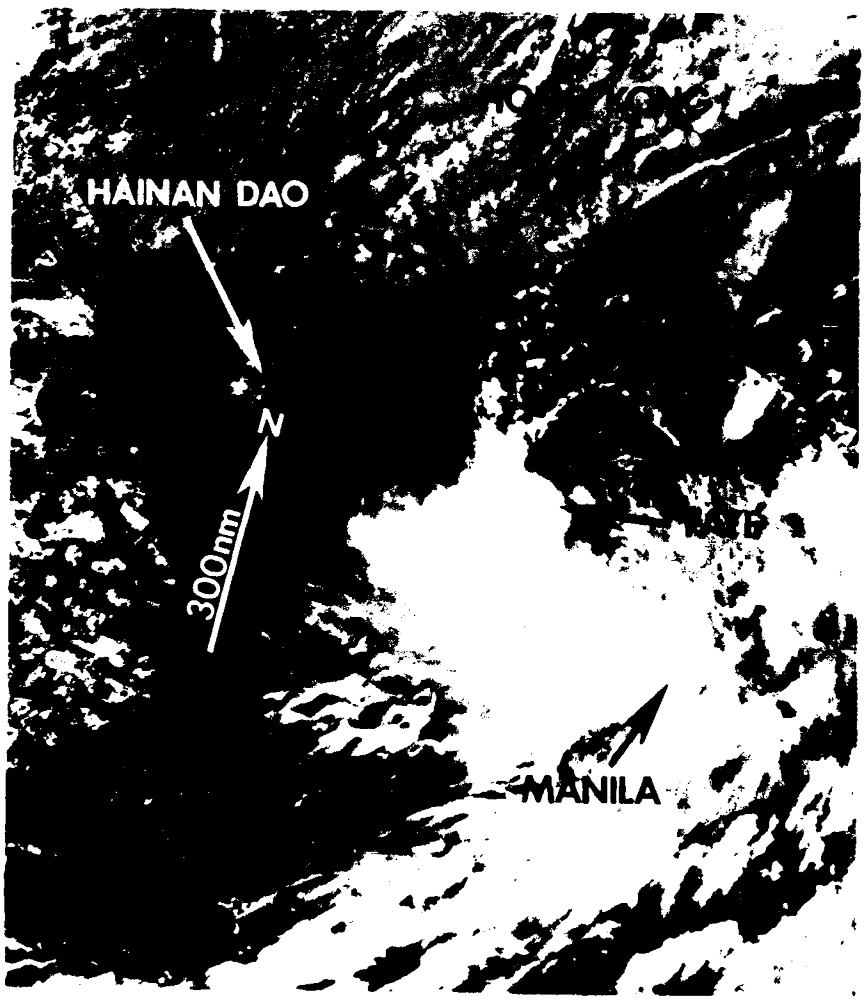


Figure 3-07-2. The exposed low-level circulation center is evidence of a shearing regime in the South China Sea (090607Z July NOAA visual imagery).

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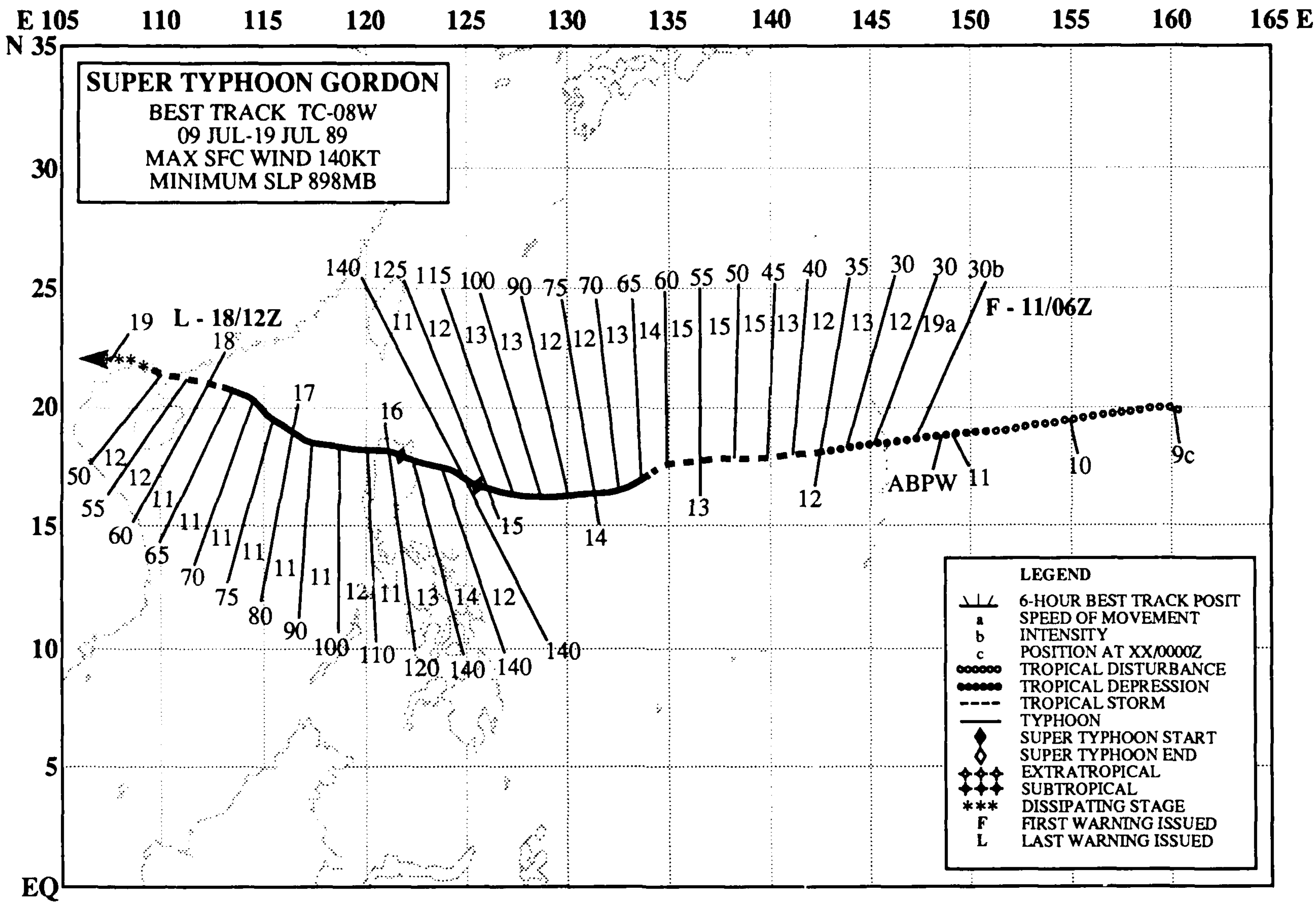

SUPER TYPHOON GORDON
BEST TRACK TC-08W
09 JUL-19 JUL 89
MAX SFC WIND 140KT
MINIMUM SLP 898MB
E 105
110
115
120
125
130
135
140
145
150
155
160
165 E
N 35
30
25
20
15
10
5
EQ
L - 18/12Z
F - 11/06Z
ABPW
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

SUPER TYPHOON GORDON (08W)

The second super typhoon in the western North Pacific for 1989, Gordon was also the second of seven significant tropical cyclones to form in July. The system was unique in that it developed from a single cumulonimbus directly beneath a cyclonic cell in the Tropical Upper-Tropospheric Trough (TUTT). The cumulonimbus was initially small, but underwent a dramatic rapid, almost explosive, deepening phase.

At the start of the second week of July, Tropical Storm Faye (07W) was affecting the Philippine Islands. Aloft, the TUTT, which

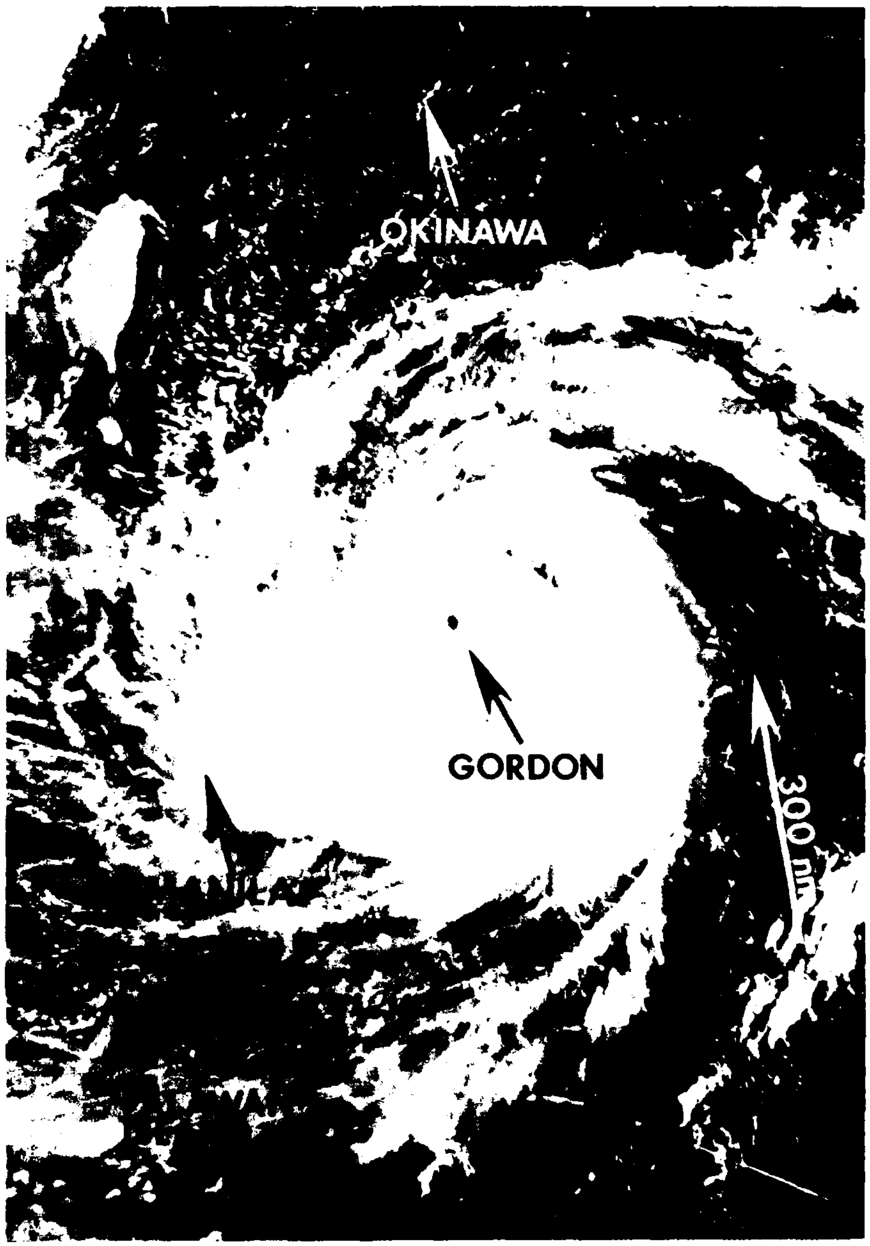


Figure 3-08-1. Typhoon Gordon four hours before reaching super typhoon intensity. The eye diameter is 20 nm (37 km) (142304Z July DMSP visual imagery).

extended eastward, was the major upper-tropospheric feature. It overlaid an extensive cloud minimum area that extended eastward to the date line. Just to the west of Wake Island on 9 July, a discrete cloud system became associated with a deep TUTT low.

On 11 July after the early morning convective maximum, a very small, ragged central dense overcast persisted, and the Significant Tropical Weather Advisory was reissued at 110200Z to include the system. Subsequent satellite imagery indicated the system's vigorous central convection was expanding rapidly, too rapidly to enable JTWC to issue a Tropical Cyclone Formation Alert. As a result, an abbreviated warning was issued on Tropical Depression 08W at 110400Z, followed by the first 72-hour warning at 110600Z. This development was unusual. Gordon appeared to blossom directly beneath the upper cold low. This was in contrast to the normal sympathetic development of convection to the south and east of the upper low (Sadler, 1976). To our knowledge such a distal development has never been documented. Sadler (1974) does discuss a similar development where convection wraps around the TUTT cell, finally converting the cold-core cyclone to a warm-core one. This is generally a slow process. He also alludes to occasional cumulonimbus near the center of TUTT cells as a clue to locating their centers, but does not discuss the development of tropical cyclones from the thunderstorms.

The system's track was west-southwest to westward for two days, becoming west-northwestward as Gordon approached the Philippine Islands. The guidance from the NOGAPS fields correctly foretold that no break in the subtropical ridge would occur, and that Gordon's westward movement would be uninterrupted.

Initially, forecasters expected slow to normal intensification as the TUTT restricted the system's upper-level outflow. However, the depression was quickly upgraded to Tropical

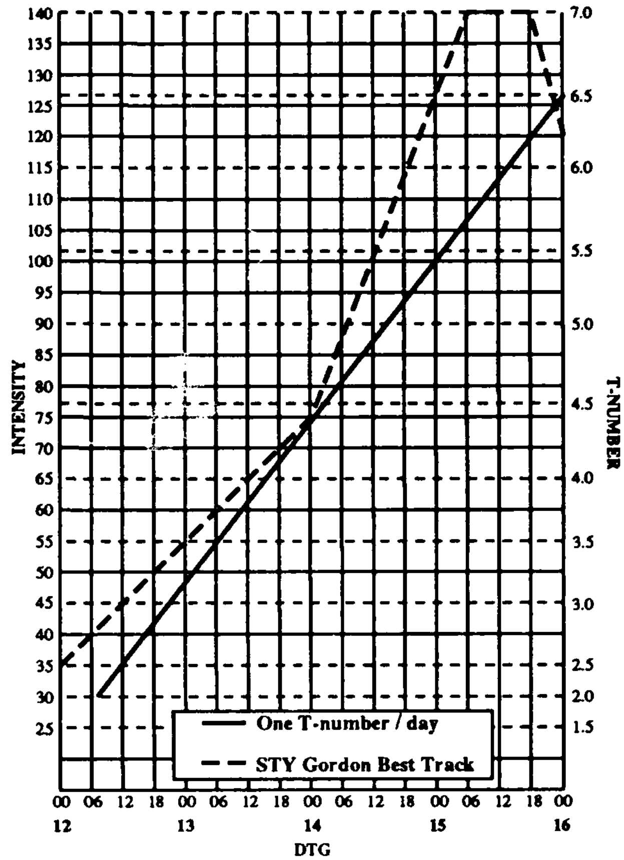


Figure 3-08-2. Gordon's rapid intensification after 140000Z compared with an increase of one "T" number per day.

Storm Gordon 24 hours after the initial warning, to typhoon after 48 hours, and to super typhoon after 96 hours (Figure 3-08-1). In only 30 hours from 140000Z to 150600Z, Gordon intensified rapidly - two-and-one-half "T" numbers (Figure 3-08-2). This represents an estimated 70-mb fall in central pressure over this period, or a deepening rate of 2.3 mb/hr, just short of the 2.5 mb/hr required for explosive deepening (Dunnavan, 1981).

Super Typhoon Gordon slammed into the rice-producing region of northern Luzon with maximum sustained winds of 140 kt (72 m/sec). News reports indicated that 27 people died, 15 were missing, at least 120,000 were evacuated and thousands were left homeless in its wake . To the south, the peak winds reported from US military installations in the Philippines were 68 knots (35 m/sec) at Wallace AS, 54

knots (28 m/s) at John Hay AB, 40 kt (21 m/sec) at Cubi Point NAS (WMO 98426), and 18 kt (9 m/sec) at Clark AB(WMO 98327). John Hay AB also recorded a total of 29.8 inches (747 mm) of rain. The **SS OVERSEAS VIVIAN** reported 35 kt (18 m/sec) sustained winds as it approached Subic Bay late on 15 July when Gordon was more than 200 nm (370 km) away.

After exiting northern Luzon, the typhoon moved west-northwestward across the South China Sea and passed 100 nm (185 km) to the southwest of Hong Kong at 171800Z (Figure 3-08-3). U.S. Navy ships in port at Hong Kong had sortied 24 hours earlier. Though the system was weakening as it made landfall near the coastal city of Zhanjiang, 215 nm (398 km) west-southwest of Hong Kong, where Gordon inflicted more fatalities and property loss. The final warning was issued at 181200Z, as Gordon left the Leizhou peninsula.

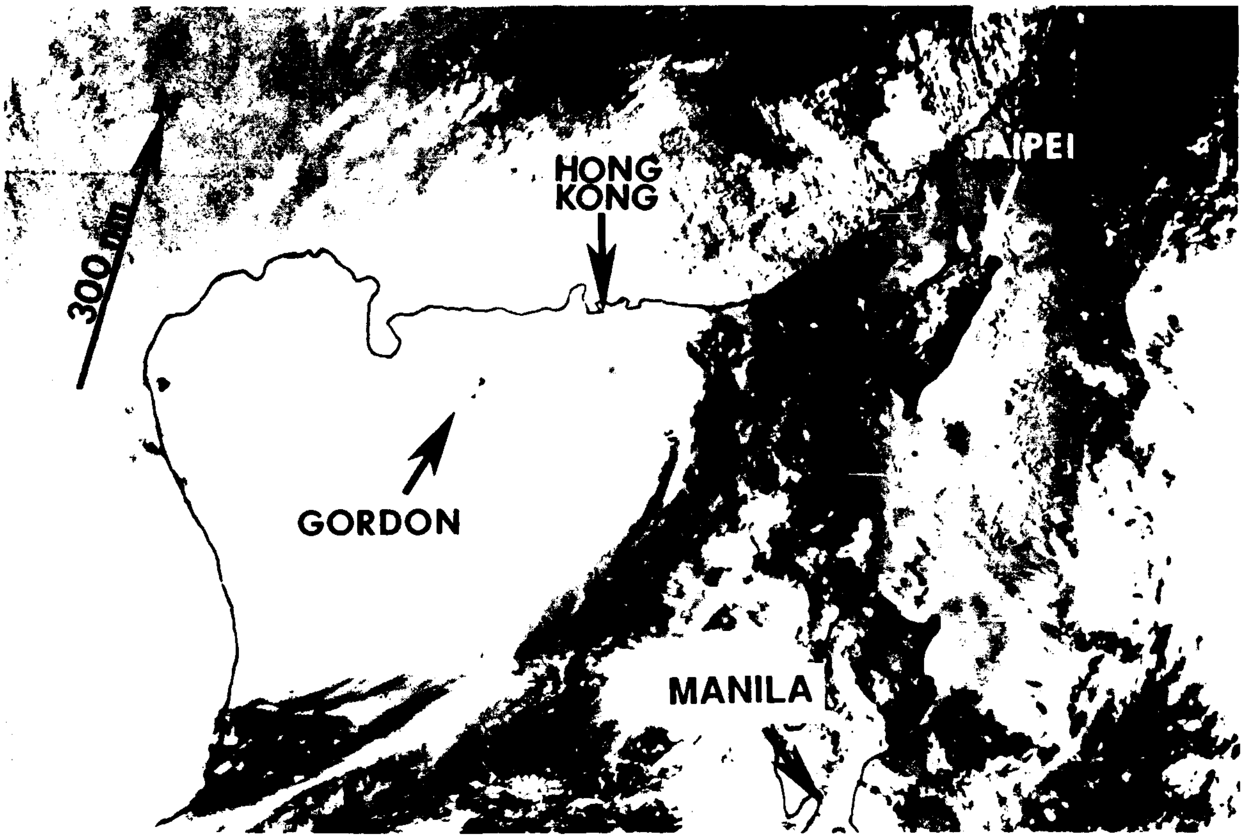
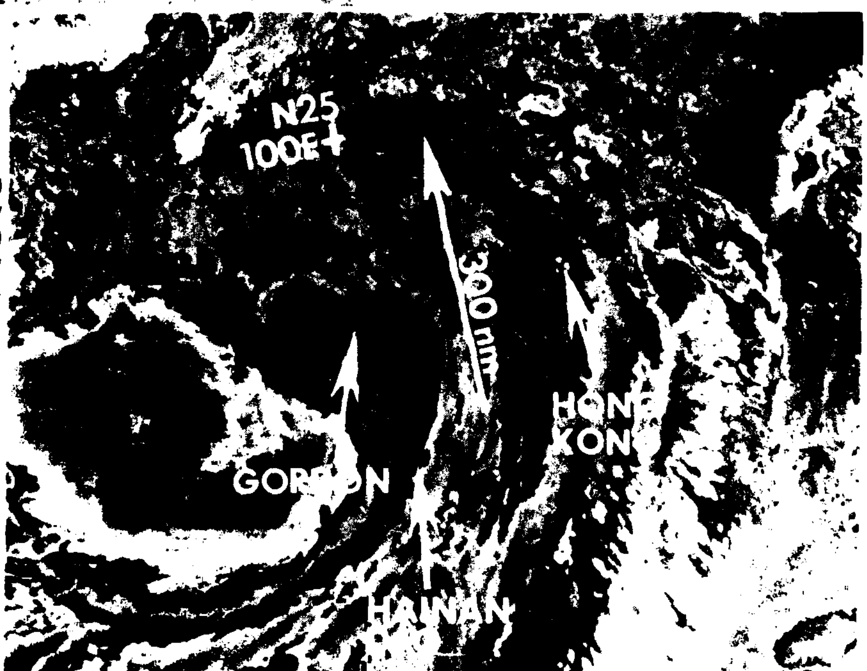


Figure 3-08-3. The large ragged eye is visible as Tropical Storm Gordon moves southwest of Hong Kong (180126Z July DMSP visual imagery).

During the next three hours, Gordon's area of convection (Figure 3-08-4) expanded nearly three times in size as it moved across the shallow, warm waters of the Gulf of Tonkin. Synoptic data indicated continued weakening during the convective expansion. The remnants of Gordon were identifiable on satellite imagery for the next 24 hours as the dissipating system moved into the mountains of northern Vietnam.

Figure 3-08-4. Tropical Storm Gordon (above) enters northern Gulf of Tonkin (181115Z July DMSP enhanced infrared imagery) and (below) Gordon's area of convection expands rapidly (181407Z July DMSP enhanced infrared imagery).



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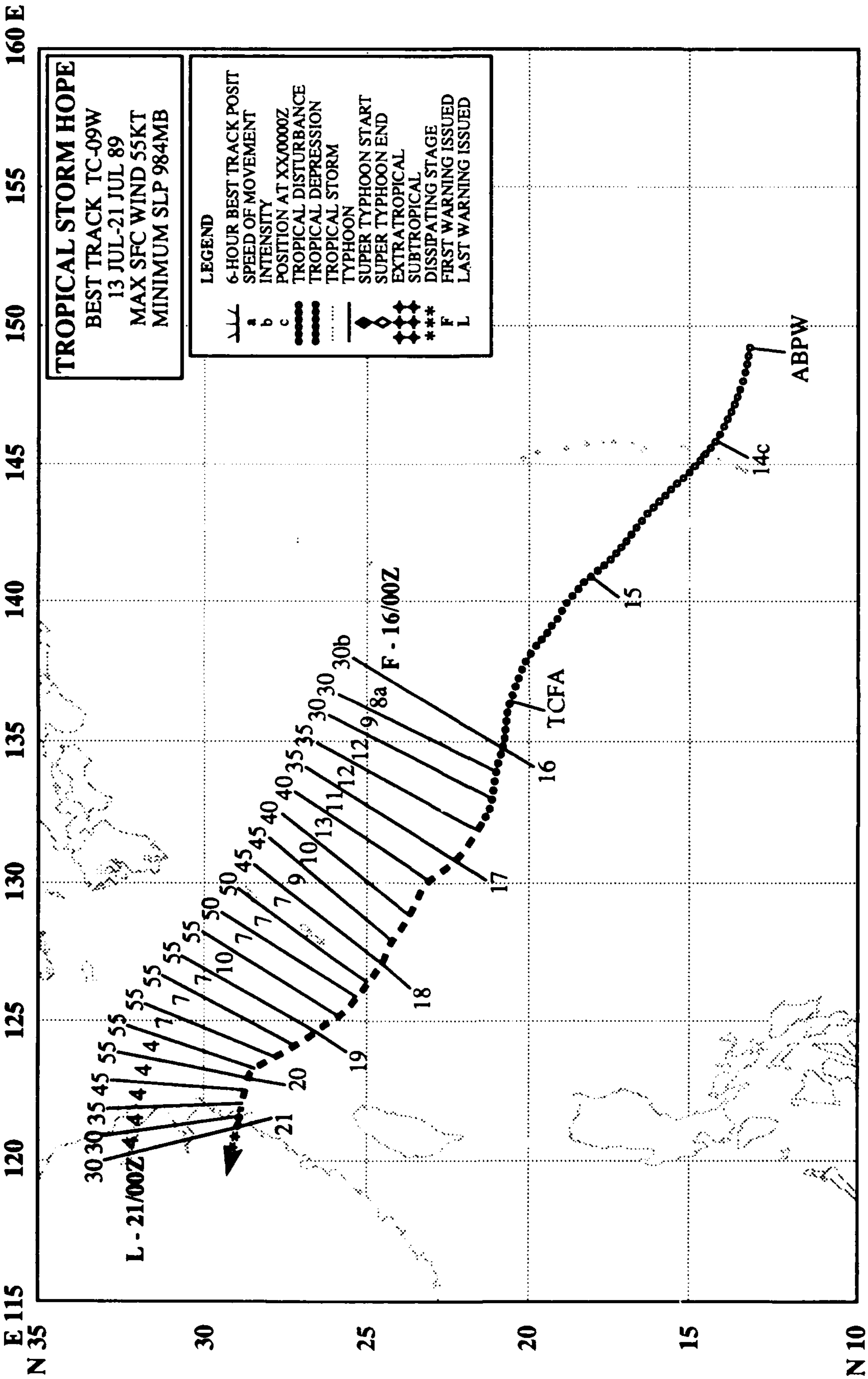

TROPICAL STORM HOPE
BEST TRACK TC-09W
13 JUL-21 JUL 89
MAX SFC WIND 55KT
MINIMUM SLP 984MB
LEGEND
6-HOUR BEST TRACK POSIT
SPEED OF MOVEMENT
INTENSITY
POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
ABPW
14c
15
TCFA
16
17
18
19
20
21
F - 16/00Z
L - 21/00Z
E 115
120
125
130
135
140
145
150
155
160 E
N 35
30
25
20
15
N 10

TROPICAL STORM HOPE (09W)

The third of seven tropical cyclones to form in July, Hope was a TUTT-induced tropical cyclone that failed to develop to typhoon intensity as a result of the upper-level shear from outflow from Super Typhoon Gordon (08W). During its life, Hope moved generally northwestward , occasionally "stair-stepping" in response to the passage of a series of mid-latitude short-wave troughs. Although no binary interaction was apparent, the tropical cyclone tracked along the periphery of Gordon's low-level inflow for most of its lifetime.

Hope generated in the wake of Gordon (08W) in a broad area of convection enhanced by the divergence aloft associated with a TUTT cell. When the convection persisted for more than 18 hours, it was included as a suspect area on the Significant Tropical Weather Advisory at 130600Z. Synoptic data indicated a low-level cyclonic circulation embedded in the convection. Surface winds were estimated to be 10 to 20 kt (5 to 10 m/sec) and the MSLP 1007 mb. During the next 48 hours, the convection became disorganized due to increased vertical wind shear aloft from Super Typhoon Gordon (08W), which was intensifying to the west. A weak surface circulation persisted in the synoptic data.

At 151740Z JTWC issued a Tropical Cyclone Formation Alert when Hope's central convection increased after the combined restrictive effects of the passage of a mid-latitude trough to the north and outflow from Gordon (08W) to the west decreased. Winds in the area were estimated to be 20 to 30 kt (10 to 15 m/sec). The first warning followed at 160000Z. Tropical Depression 09W tracked westward for the next 18 hours under the influence of the building mid-tropospheric subtropical ridge to the north. The low-level circulation center remained partially exposed until 161800Z, when a central dense overcast formed. In response, Hope intensified to 35 kt (17 m/sec) and was upgraded to a tropical storm.

Late on 16 July, Hope's track returned to the northwest in contrast to the guidance provided by the NOGAPS forecast fields, which indicated the subtropical ridge would remain intact despite the approach of a series of short-wave troughs. The NOGAPS guidance was reinforced by the statistical-dynamic aid CSUM. As a result, JTWC adjusted the forecast track southward with each succeeding warning until, by 171800Z, Hope was forecast to pass near Taiwan. However, the tropical cyclone remained north of the forecast track and slowly intensified. Kadena AB (WMO 47931) on Okinawa, approximately 100 nm (185 km) northeast of the tropical storm, measured a peak gust of 31 kt (16 m/sec) at 180411Z.

From 180000Z through 191800Z the

synoptic situation was complex (Figure 3-09-1). Hope responded to another short-wave trough and tracked north-northwestward . Once again JTWC abandoned the westward track into China and changed the forecast track to take Hope through a possible break in the subtropical ridge into the East China Sea and then on to Korea. The change in track was prompted by several factors: (1) the failure of the expected westward movement to develop, (2) the possibility that NOGAPS was overforecasting the strength in the ridge to the north, (3) the expectation that Hope would remain a shallow system and be influenced by the more southerly low- to mid-level steering flow rather than the weak easterly mid- to upper-level flow, and (4) guidance from the dynamic aid OTCM. However, after the passage of another short-wave trough, the ridge strengthened north of Hope. At 200000Z, the tropical storm (Figure

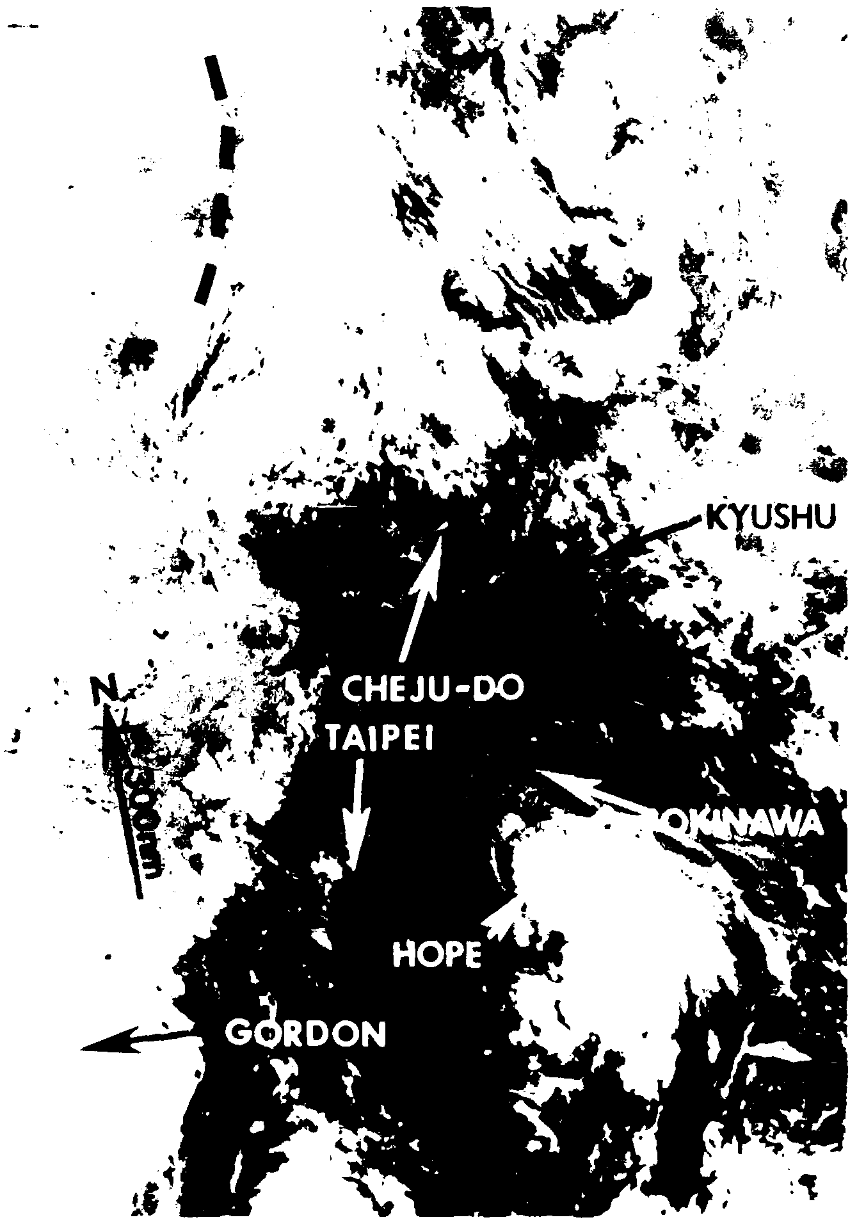


Figure 3-09-1. Complex synoptic situation with Gordon (08W) to the west, and the mid-latitude trough to the north. The island of Okinawa is nearby (172338Z July NOAA visual image.)

3-09-2) executed an abrupt turn to the west and moved into mainland China.

While Hope was over warm ocean waters, it intensified slowly, reaching its peak intensity of 55 kt (27 m/sec) at 181800Z. However, the northeasterly upper-level flow restricted Hope's outflow and prevented further development into a typhoon. Hope was downgraded to a tropical depression at landfall. The tropical cyclone weakened rapidly as it moved over land, and the final warning was issued at 210000Z. News reports indicated that at least 24 people died and more than 1000 were injured in eastern China. In addition, landslides and widespread flooding resulted from locally heavy rains. Totals up to 7.5 inches (109 mm) in 24 hours were recorded in some areas.

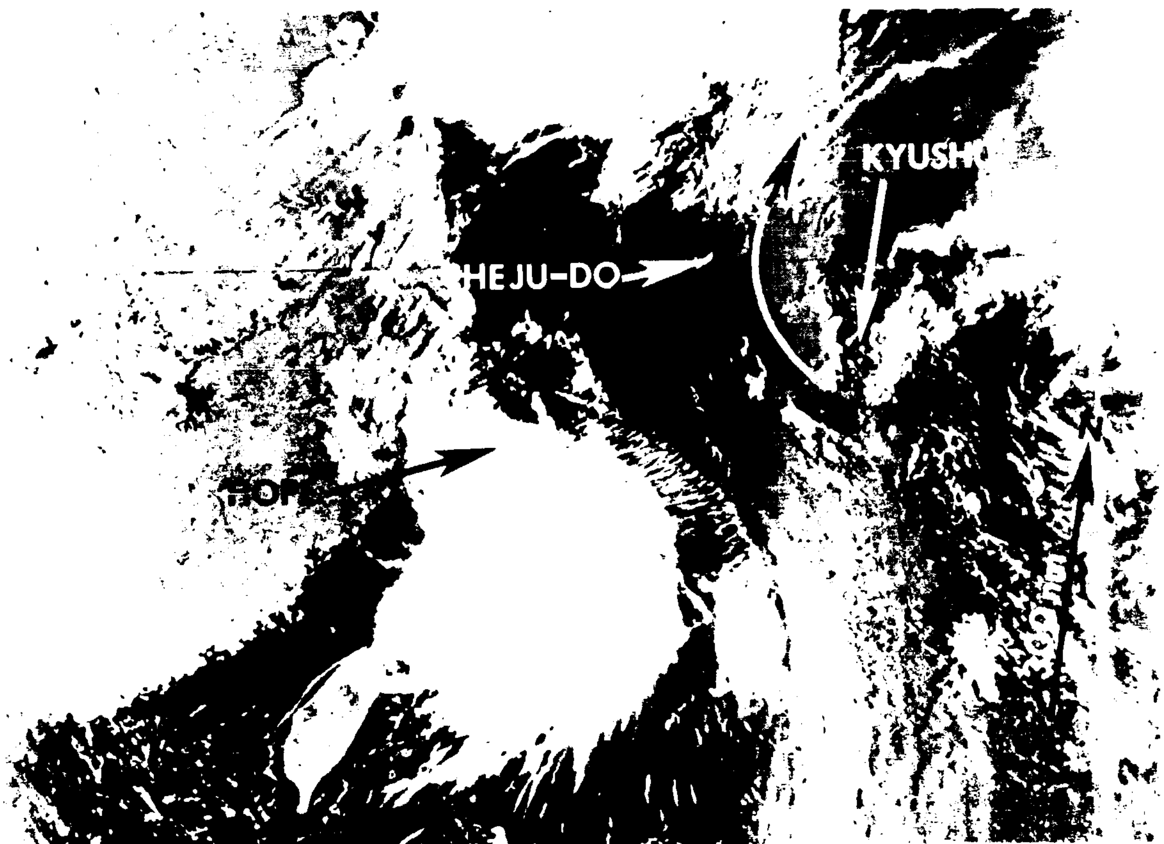
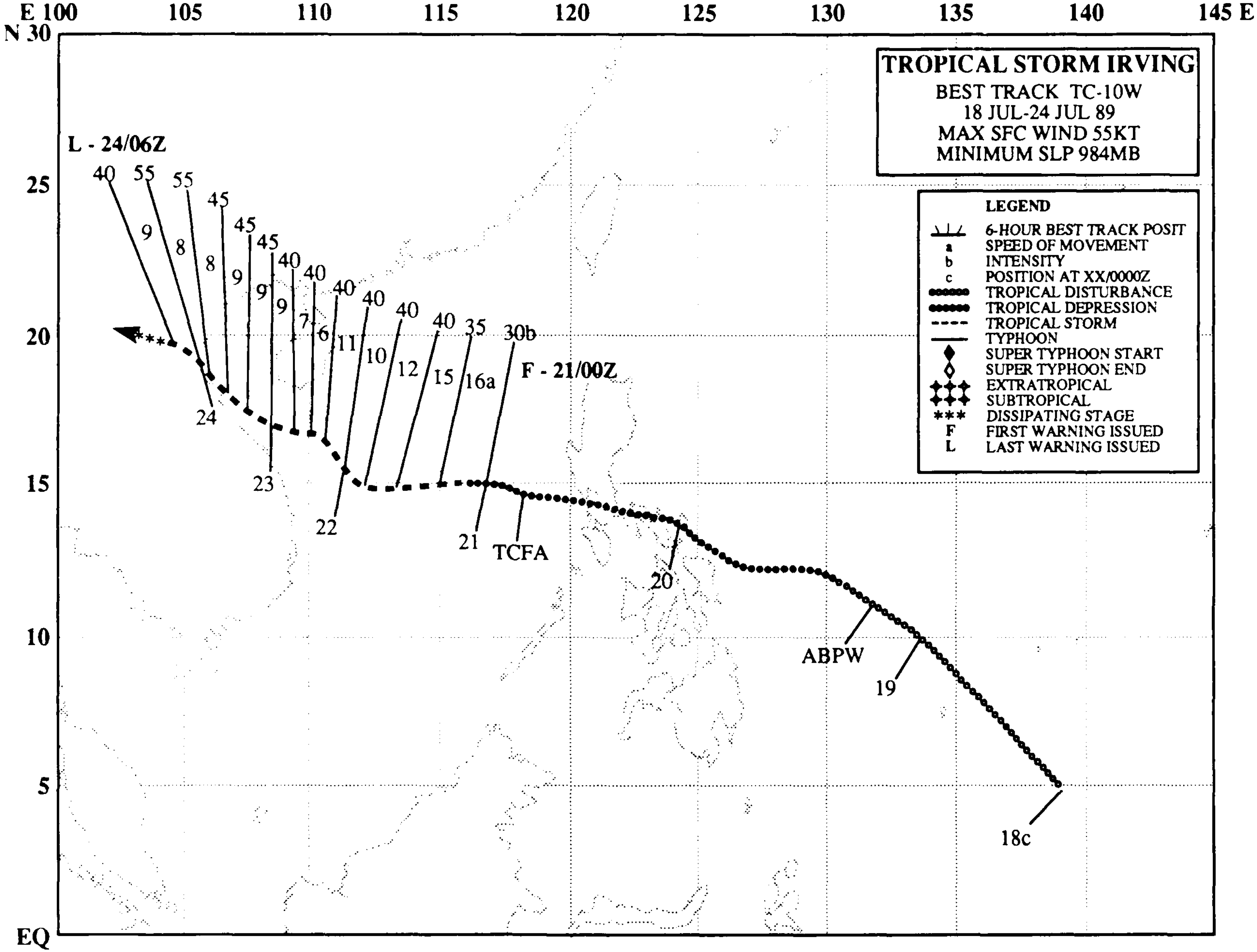


Figure 3-09-2. Hope near landfall. The low-level anticyclonic flow (indicated by the curved arrow) in the subtropical ridge is defined by the cumulus streets across southern Korea, coastal China, and the brightness pattern in the lee of Kyushu. Frontal cloudiness associated with the passing trough trails across central Korea and the Yellow Sea (200046Z July DMSP


TROPICAL STORM IRVING
BEST TRACK TC-10W
18 JUL-24 JUL 89
MAX SFC WIND 55KT
MINIMUM SLP 984MB
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 100
105
110
115
120
125
130
135
140
145 E
N 30
25
20
15
10
5
EQ
L - 24/06Z
F - 21/00Z
30b
16a
TCFA
ABPW
18c
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TROPICAL STORM IRVING (10W)

Tropical Storm Irving was the fourth tropical cyclone of 1989 to cross the South China Sea and the last to enter the South China Sea until Typhoon Brian (27W) late in September. In August and September the tropical cyclone tracks shifted northward. Irving was short-lived and actually reached its maximum intensity as it made landfall on the coast of northern Vietnam.

As Super Typhoon Gordon (08W) was about to make landfall on the coast of China and Tropical Storm Hope (09W) was reaching peak intensity, the disturbance that would eventually develop into Irving formed on 18 July in the monsoon trough near the southwestern Caroline Islands. The disturbance moved slowly northwestward across the Philippine Sea. Synoptic data at 190000Z July indicated a surface circulation, and the disturbance was considered a suspect area on that day's Significant Tropical Weather Advisory.

The disturbance crossed the Philippine Sea from southeast of Palau to over the Philippine Islands in three days. The lowest observed minimum sea-level pressure was 1004 mb. Once in the South China Sea, the disturbance became better organized and JTWC issued a Tropical Cyclone Formation Alert at 202000Z. The first warning on Tropical Depression 10W was issued four hours later. The depression was upgraded to tropical storm intensity at 210600Z.

The tropical easterly jet was weakly established across the Southeast Asia; still, the vertical wind shear over the South China Sea due to the northerly flow aloft was sufficient to prevent Tropical Storm Irving (Figure 3-10-1)

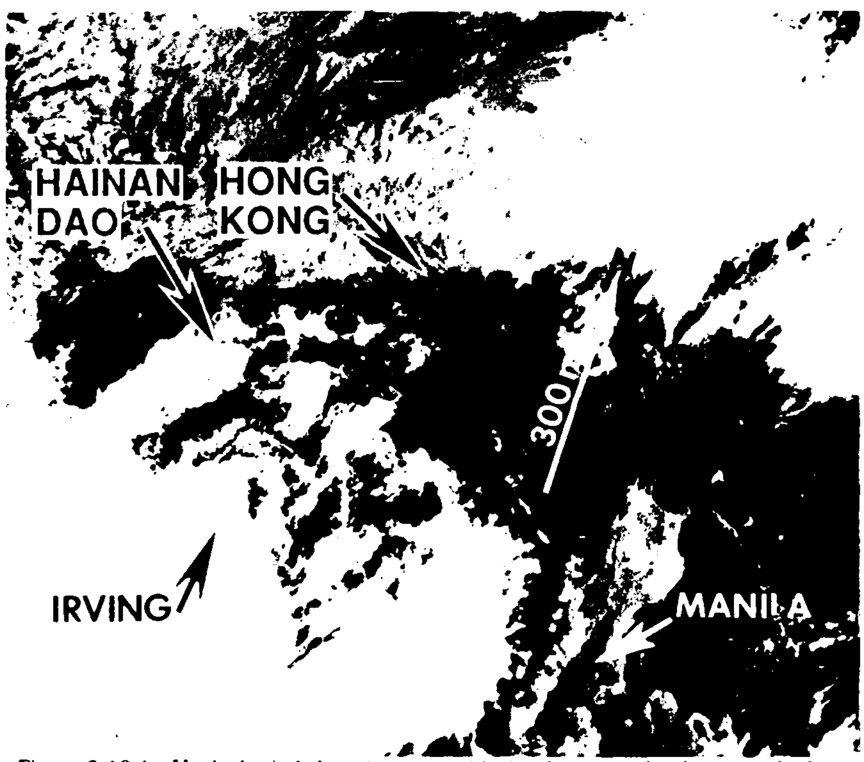

Figure 3-10-1. Vertical wind shear is responsible for the separation between the low-level circulation center and the bright cloud tops to the southwest. The area of cloudiness at the top right of the picture is the remnants of Tropical Storm Hope (09W) over eastern China (NOAA visual imagery 220533Z July).

from reaching typhoon intensity. Throughout Irving's lifetime, the upper-level cloud circulation center was located southwest of the low-level center. As a result, the nighttime infrared satellite fixes of the upper-level cloud features were displaced to the southwest of the low-level circulation center. This tilt to the system also resulted in differences between the radar and corresponding satellite fixes.

Based on satellite imagery, Irving was downgraded to a tropical depression on the 230600Z warning. However, a reanalysis of the imagery indicated Irving actually continued to intensify as it entered the warm waters of the Gulf of Tonkin. In addition, the Gulf of Tonkin is a natural region of forced low-level convergence due to the surrounding topography. The 240000Z warning upgraded the system again to tropical storm intensity. Irving was downgraded for a second time to a tropical depression on the final warning when it moved into northern Vietnam at 240600Z.

The remnants of Irving moved across the mountains and dissipated over Laos. News reports estimated that at least 102 people died and another 488 were injured in Vietnam. In addition, more than 80,000 houses and 160,000 acres of crops were destroyed.

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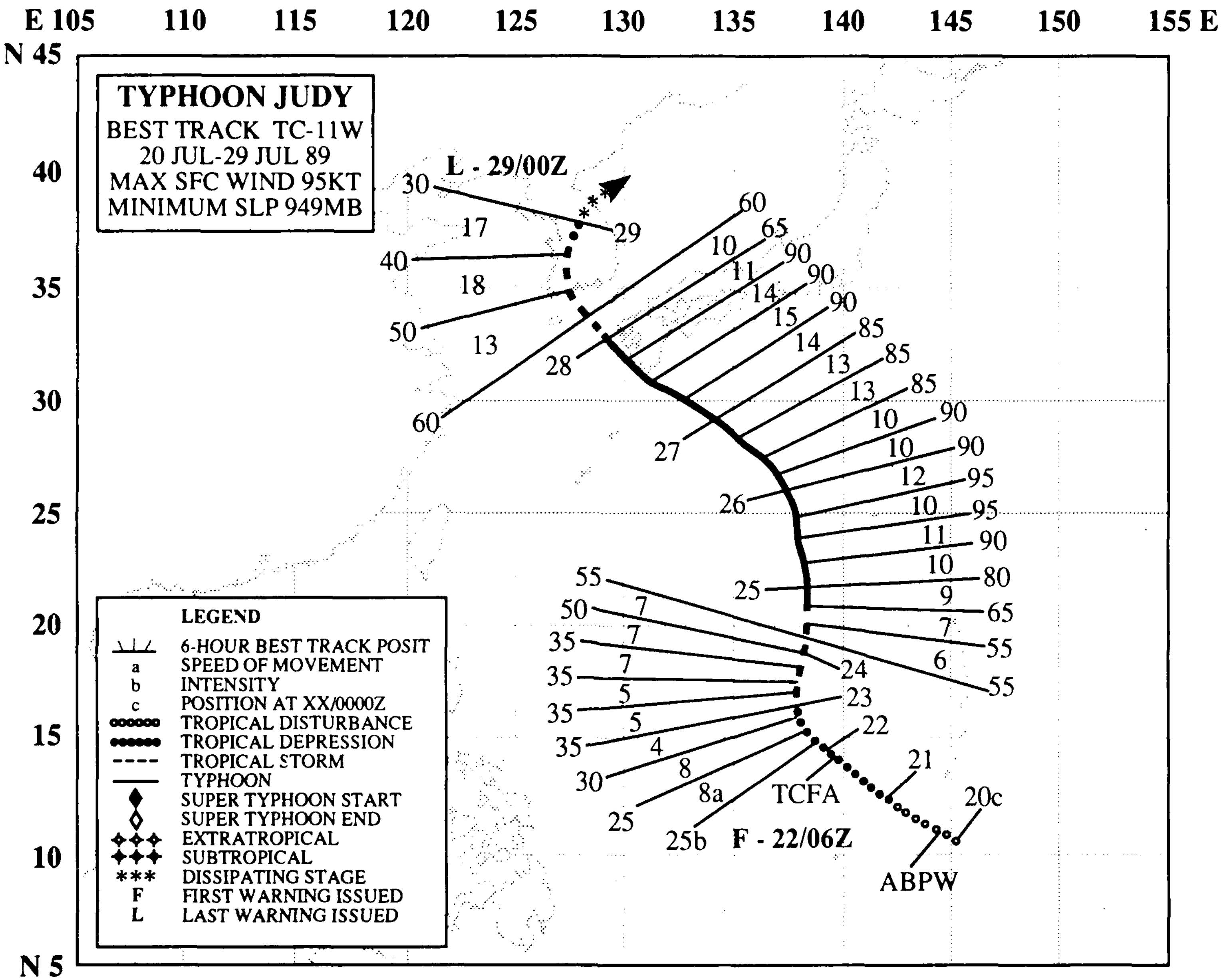
TYPHOON JUDY
BEST TRACK TC-11W
20 JUL-29 JUL 89
MAX SFC WIND 95KT
MINIMUM SLP 949MB
E 105
110
115
120
125
130
135
140
145
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155 E
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N 5
L - 29/00Z
F - 22/06Z
TCFA
ABPW
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TYPHOON JUDY (11W)

The second of two typhoons to develop during the month of July, Judy formed just west of Guam in the monsoon trough and followed a north oriented track with a critical turn to the northwest, just to the south of Honshu. It crossed the southern coast of Kyushu, made landfall on the south coast of the Korean Peninsula and dissipated rapidly.

As Tropical Storm Hope (09W) weakened over China, two tropical cyclones developed in the monsoon trough which was located near 10° north latitude. First, on July 20, Tropical Storm Irving (10W) developed in the South China Sea. The following day Judy developed 300 nm (555 km) west of Guam. The disturbance that was to become Judy was first mentioned on the Significant Tropical Weather Advisory at 200600Z as a slowly moving tropical disturbance with a poor potential for further development. The potential was upgraded to fair the following day. At 212000Z, JTWC issued a Tropical Cyclone Formation Alert based on synoptic data that indicated a low-level cyclonic circulation beneath an upper-level anticyclone and satellite imagery that showed increased convection and organization.

As the disturbance's organization and upper-level outflow continued to improve, the first warning followed for Tropical Depression 11W at 220600Z when satellite intensity analysis indicated surface winds of 25 kt (13 m/sec). A cyclonic circulation in the Tropical Upper Tropospheric Trough (TUTT)(Sadler, 1976) to the northwest of the depression provided a source of upper-level divergence needed for further intensification. At 230000Z, the depression was upgraded to tropical storm intensity when satellite analysts estimated 35-kt (18-m/sec) surface winds were present. Judy continued to intensify as the system stayed southeast of the TUTT low, a favorable position for development. At 250600Z, it was again upgraded — this time to a typhoon (Figure 3-11-1). Although most ships avoided Judy's dangerous winds, the moored buoy (WMO

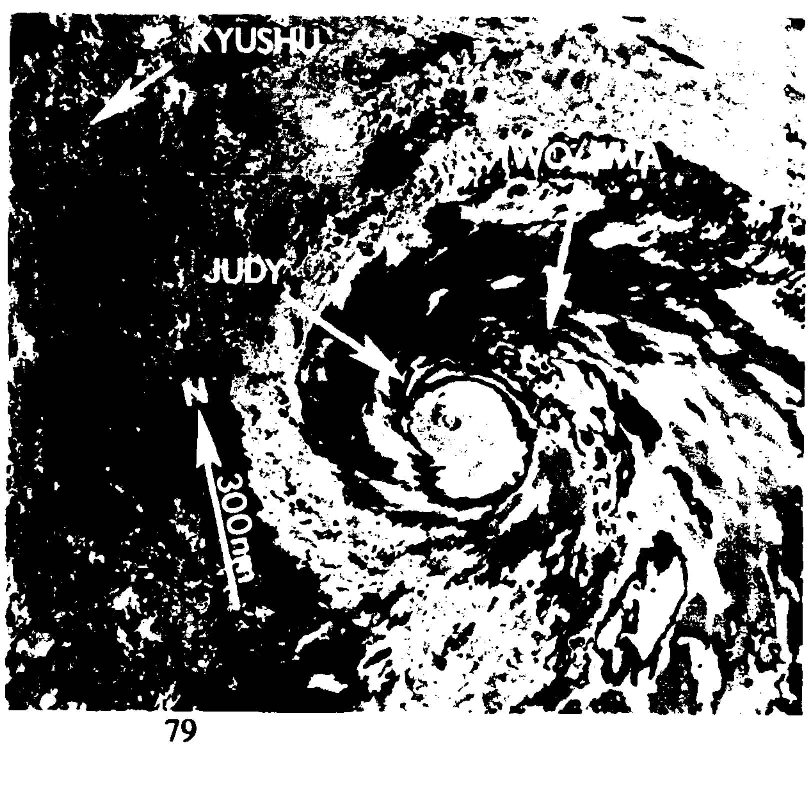

Figure 3-11-1. Judy approaching peak intensity (250945Z July DMSP enhanced infrared imagery).

21004) at 29° north latitude and 135° east longitude provided valuable data to track Judy. Fifty-seven-knot (29 m/sec) winds and a minimum sea-level pressure of 974 mb were recorded as the typhoon passed close by.

Using NOGAPS and satellite data as a guide, JTWC forecast Judy to track northward to Japan and then recurve to the northeast. In contrast, OTCM guidance suggested a northwestward track from the start. When the subtropical ridge did finally build in from the east, OTCM was discounted since all the previous model guidance (Figure 3-11-2) indicated a northwest track while July tracked north. By comparison, Figure 3-11-3 shows JTWC's initial success with the track forecasts. However, after the direction change on 26 July, it took a day for the forecasts to get back on track to the northwest. This situation highlighted the value of the alternate scenario and rapid communications between the customer and the forecaster when forecast difficulties arise.

Judy's interaction with the southern coast of Kyushu at 271800Z resulted in rapid weakening. This trend continued until the

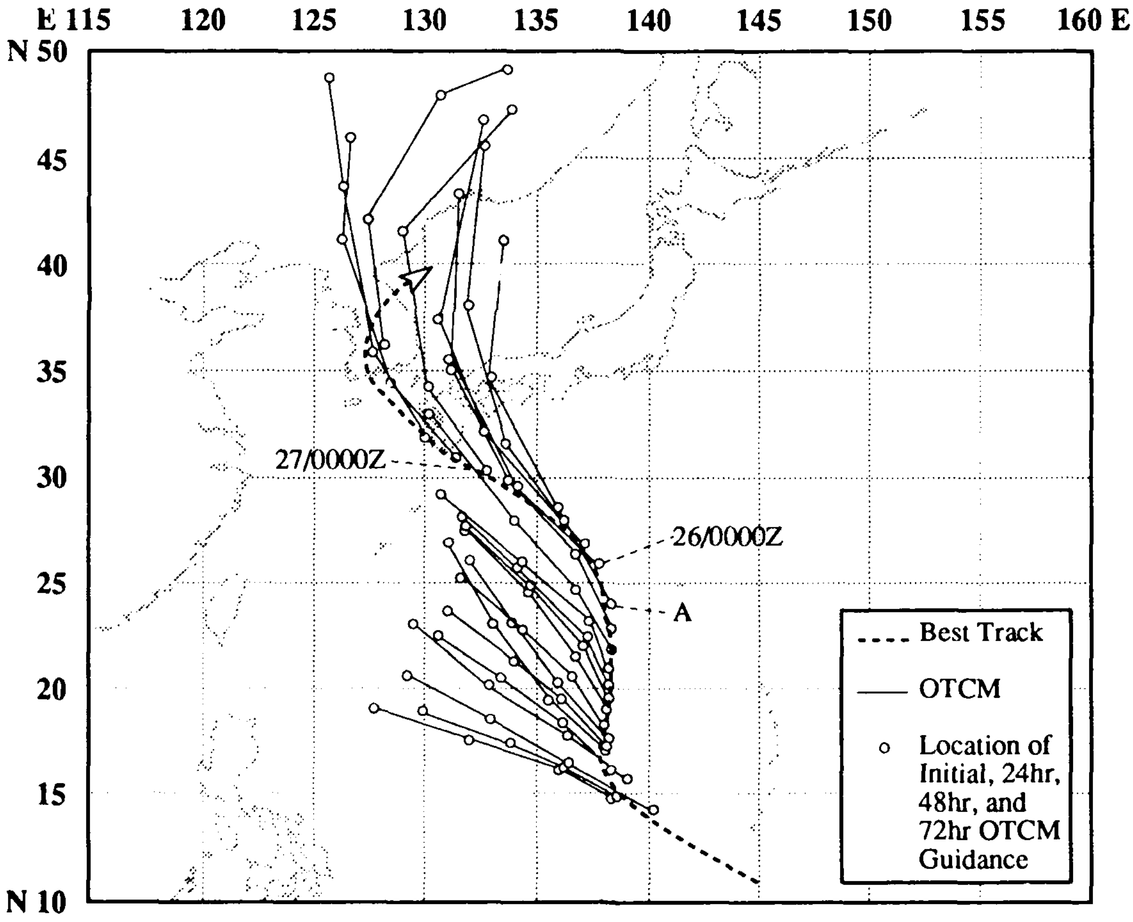

Figure 3-11-2. Comparison of OTCM guidance with the best track. After 251800Z July (point A), the guidance proved correct.

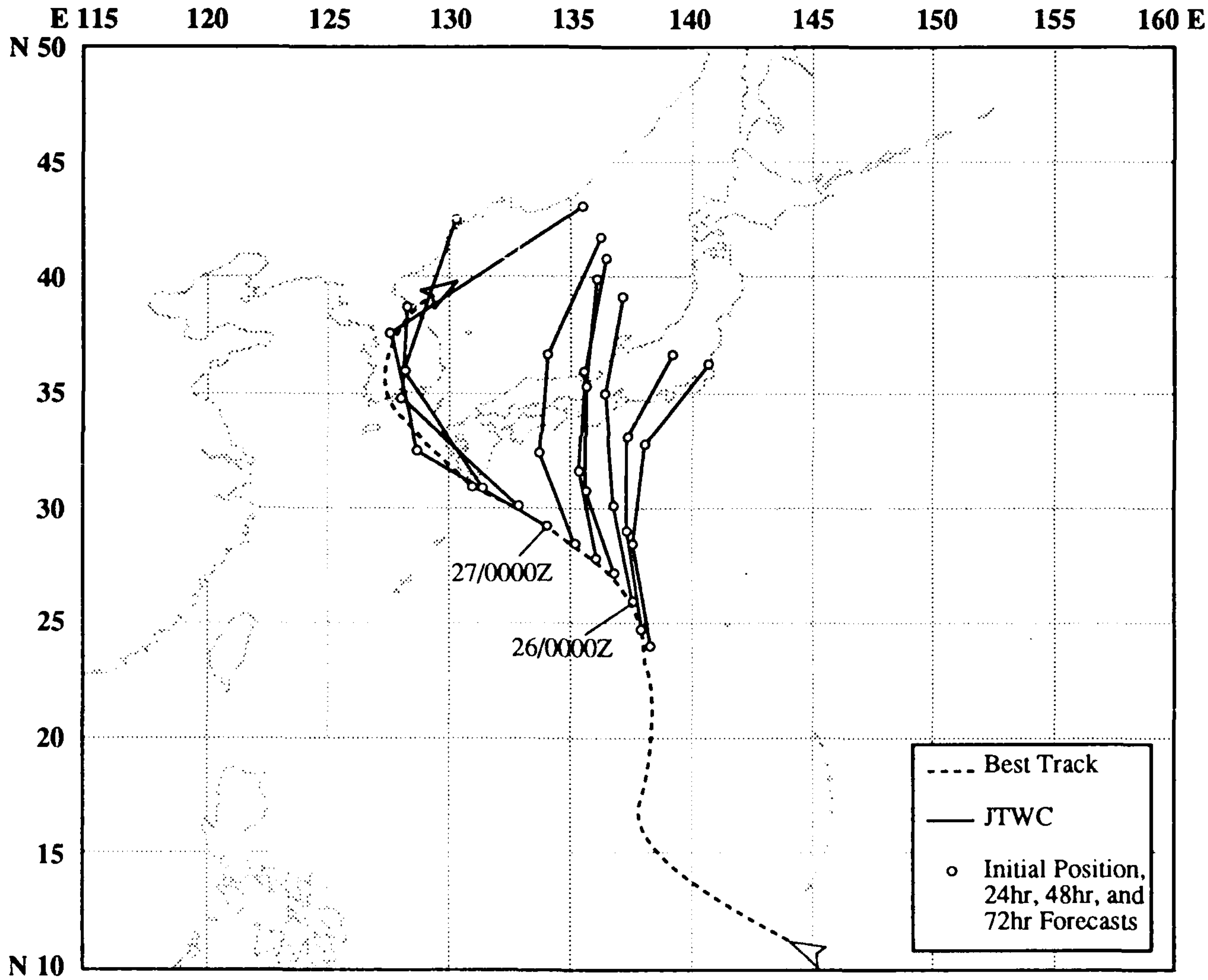

Figure 3-11-3. JTWC forecasts compared with the best track. The major track change to the northwest on 26 July was not reflected in the forecasts until the next day.

tropical cyclone (Figure 3-11-4) made landfall approximately 110 nm (205 km) southwest of Pusan, Korea. By the time Judy reached Osan AB near Seoul , it had weakened significantly. Osan AB (WMO 47122) reported maximum winds of 22 kt (11 m/sec). At 290000Z, the final warning was issued as the remnants of the system moved towards the Sea of Japan. No reports of damage were received.

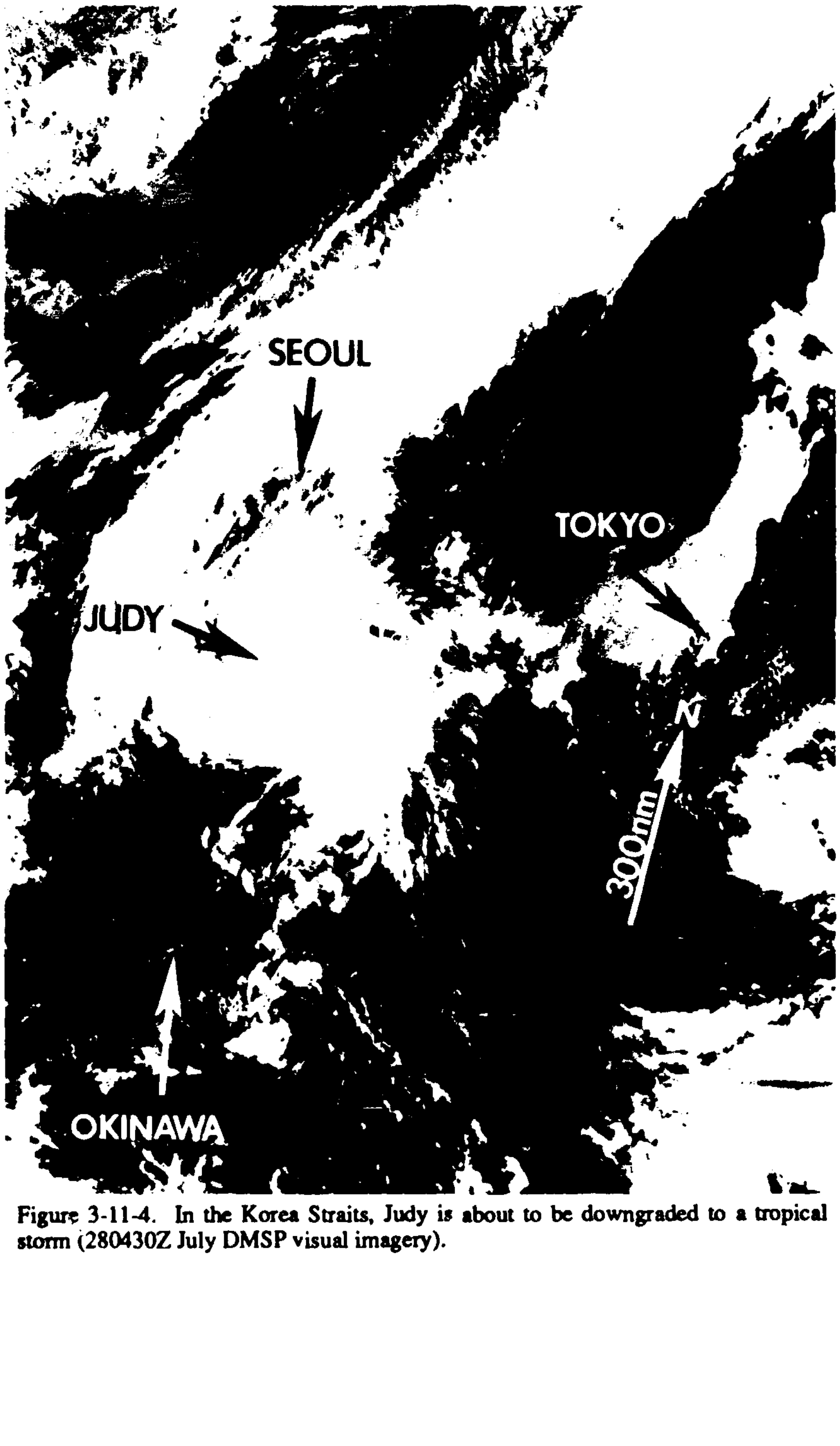

Figure 3-11-4. In the Korea Straits, Judy is about to be downgraded to a tropical storm (280430Z July DMSP visual imagery).

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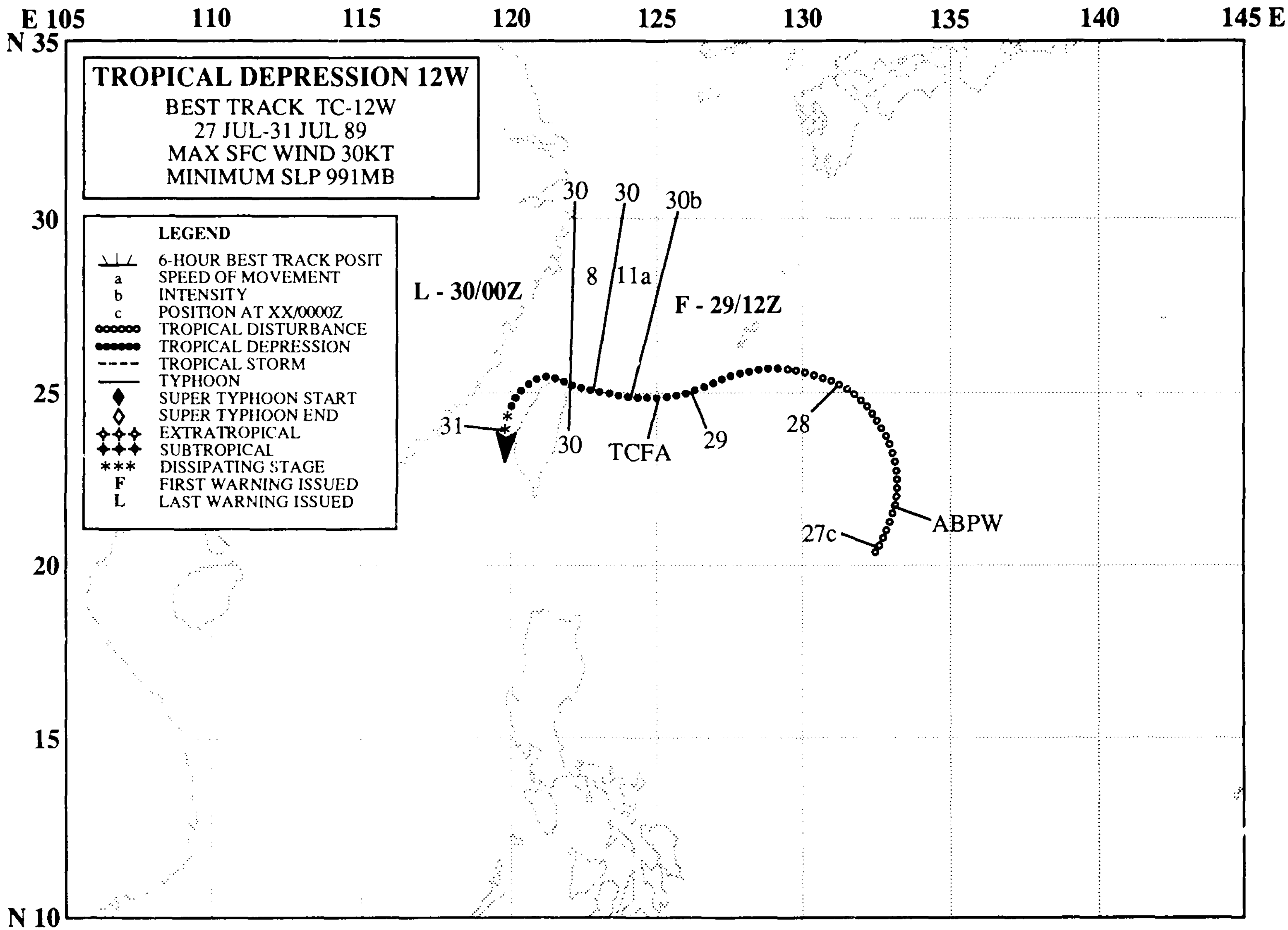
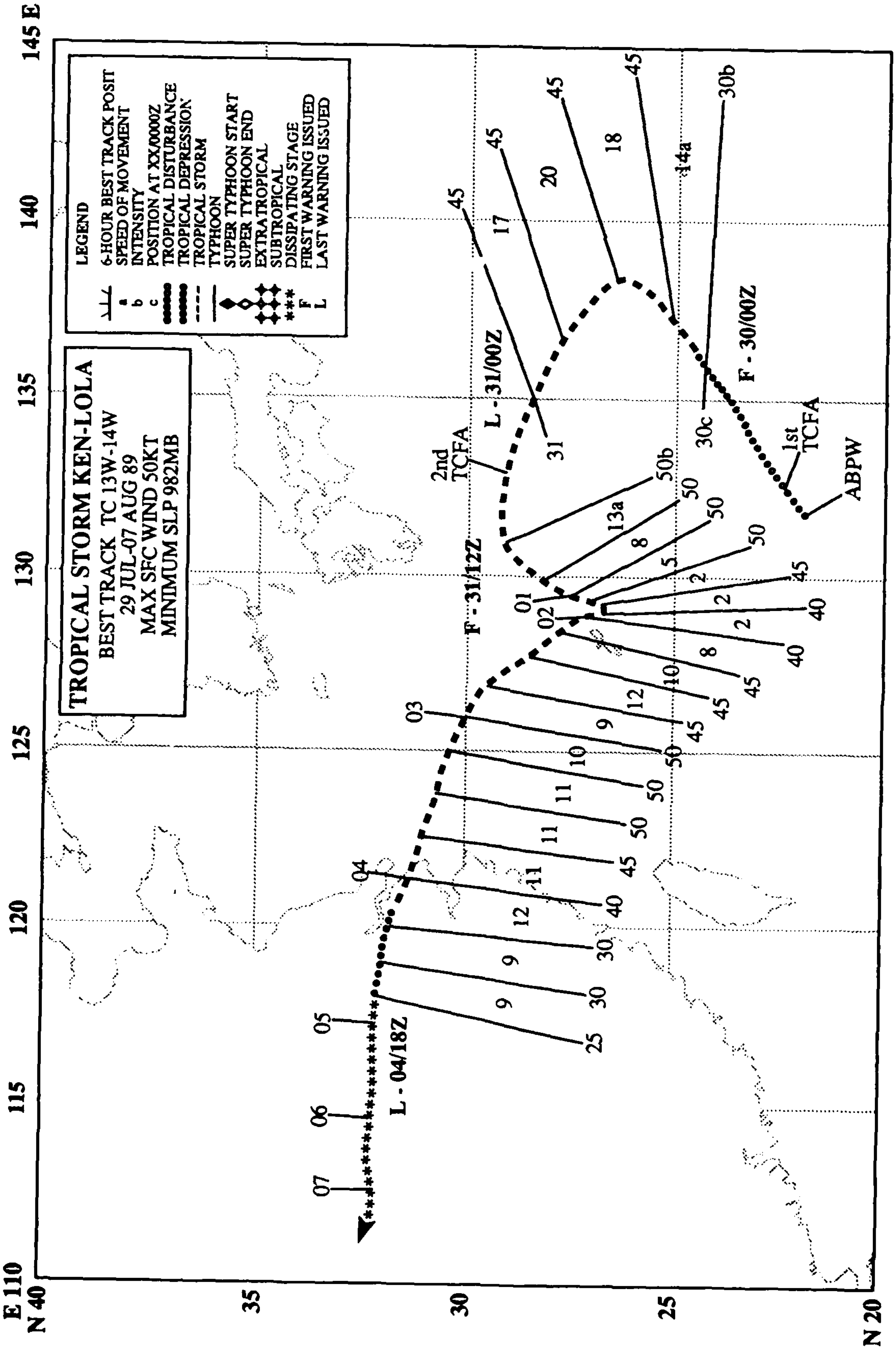

TROPICAL DEPRESSION 12W
BEST TRACK TC-12W
27 JUL-31 JUL 89
MAX SFC WIND 30KT
MINIMUM SLP 991MB
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 105
110
115
120
125
130
135
140
145 E
N 35
30
25
20
15
N 10
L - 30/00Z
F - 29/12Z
30
30
30b
8
11a
31
30
TCFA
29
28
ABPW
27c

TROPICAL DEPRESSION 12W

While Typhoon Judy (11W) was tracking northwestward towards Korea, an area of deep convection became persistent to the south-southeast of Judy. This persistent convection, first mentioned in the Significant Tropical Weather Advisory for 27 July, looped around in the monsoon trough and headed west, passing 50 nm (80 km) south of Okinawa at 281200Z. The discovery of a well-developed low-level circulation and falling pressures prompted the issuance of a Tropical Cyclone Formation Alert at 290630Z, followed by the first Tropical Depression Warning at 291200Z. Because of strong vertical wind shear, the depression was not forecast to intensify to a minimal tropical storm. After the last warning at 300000Z, the deep convection sheared away and continued westward into China while the dissipating low-level circulation tracked southward into the Taiwan Strait.

Figure 3-12-1. TD 12W shortly after the first warning (291131Z July DMSP infrared imagery).


TROPICAL STORM KEN-LOLA
BEST TRACK TC 13W-14W
29 JUL-07 AUG 89
MAX SFC WIND 50KT
MINIMUM SLP 982MB
LEGEND
6-HOUR BEST TRACK POSIT
SPEED OF MOVEMENT
INTENSITY
POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
ABPW
1st TCFA
2nd TCFA
F - 30/00Z
L - 31/00Z
F - 31/12Z
L - 04/18Z
E 110
145 E
N 40
N 20

TROPICAL STORM KEN-LOLA (13W-14W)

Tropical Storm Ken-Lola underscored the limitations of remote sensing for locating poorly organized systems. Synoptic data proved invaluable in identifying and classifying the system while in warning status and in the post-analysis. While in warning status, JTWC considered the system as two separate tropical cyclones. A detailed post-analysis, even though not absolutely conclusive, strongly suggested that Tropical Storms Ken and Lola were probably the same system. The system generated in the monsoon trough that had already proven itself the most active since July 1973. The system then took an elongated cycloidal track, passing close to Okinawa before making landfall on the coast of eastern China.

In the last week of July, as Tropical Depression 12W tracked through the southern Ryukyu's and Typhoon Judy (11W) dissipated in the Sea of Japan, an active monsoon trough with several small embedded circulation centers extended across Taiwan, eastward to 140° east longitude. A pool of warmer than normal sea surface temperatures engulfed the southern Ryukyu's and extended southeastward to 130° east longitude. On 29 July, synoptic data indicated that a circulation center in the low-level wind field formed over the warm pool about 300 nm (555 km) southeast of Okinawa. While the circulation had a central pressure of 995 mb and winds near the center of only 15 kt (8 m/sec), a broad area of southwesterly monsoonal gales extended 100 to 300 nm (185 to 555 km) south of the center. The first mention of the disturbance appeared on that day's Significant Tropical Weather Advisory as a suspect area having fair potential for development.

Further evaluation of the 290600Z synoptic data and subsequent satellite imagery led to issuance of a Tropical Cyclone Formation Alert at 290930Z even though the low-level cyclonic circulation center was displaced to the north of the associated convection. Improving organization during the subsequent 18 hours prompted the first warning on Tropical Depression 13W at 300400Z. The depression was forecast to move northward, along the periphery of the monsoon gale area, and loop cyclonically around a mid- to upper-level low located between the depression and Okinawa. This low aloft would restrict the depression's outflow and result in slow development and peaking below typhoon intensity. JTWC correctly forecast the overall character of the track and the limited intensity.

At 300900Z, the second warning valid at 300600Z, was amended to upgrade the depression to Tropical Storm Ken, when synoptic data showed the maximum sustained winds were 45 kt (23 m/sec). For the next 18 hours fixes from (mostly nighttime) satellite imagery indicated continued northeast movement until the final warning was issued at 310000Z. JTWC expected Ken to shear apart and follow the monsoon surge around the northern periphery of an exposed low-level circulation that later would be called Lola. Post-analysis suggests that the 310000Z

position was most likely 250 nm (465 km) northwest of the warning position (Figure 3-13-1) and that the low-level system had moved northwestward since 301200Z.

At 310600Z, JTWC issued a Tropical Cyclone Formation Alert for a disturbance located about 300 nm (555 km) northeast of Okinawa. The satellite imagery (Figure 3-13-2) indicated an exposed low-level center with increasing convection to the south. This system now had gales extending several hundred miles north of the center. At 311030Z, an abbreviated warning on Tropical Storm Lola was issued after the **USS Dubuque** (LPD8) reported sustained winds of 50 kt (26 m/sec) at 310300Z followed by 40 kt (21 m/sec) and falling surface pressure three hours later. Also, at 0600Z, another ship (call sign 9MTS) reported westerly winds approximately 90 nm (165 km) south of the **USS Dubuque**. These data demonstrated that the winds reported by the Dubuque were associated with a circulation center and not the tight pressure gradient near Japan (Figure 3-13-3), as initially thought.

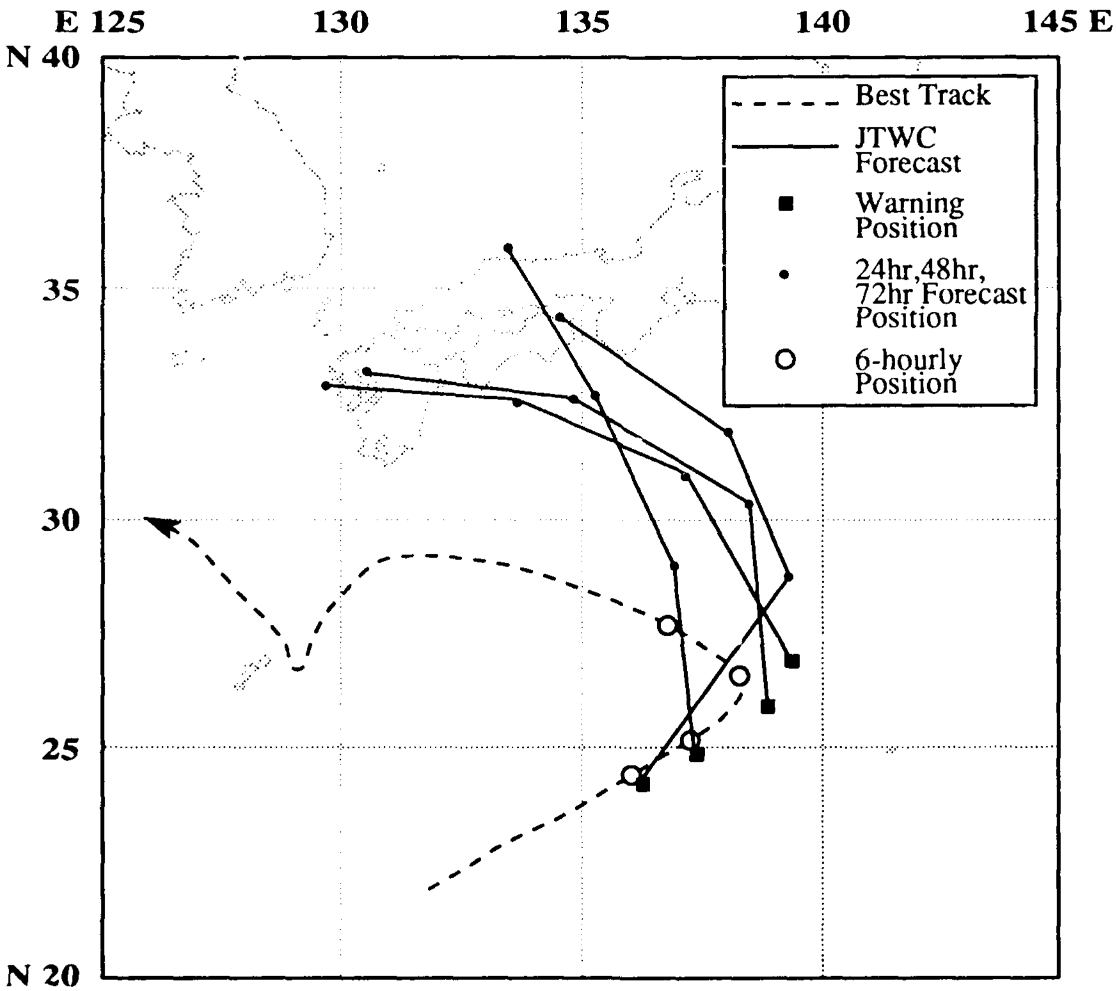


Figure 3-13-1. Ken's expected track verses the best track.

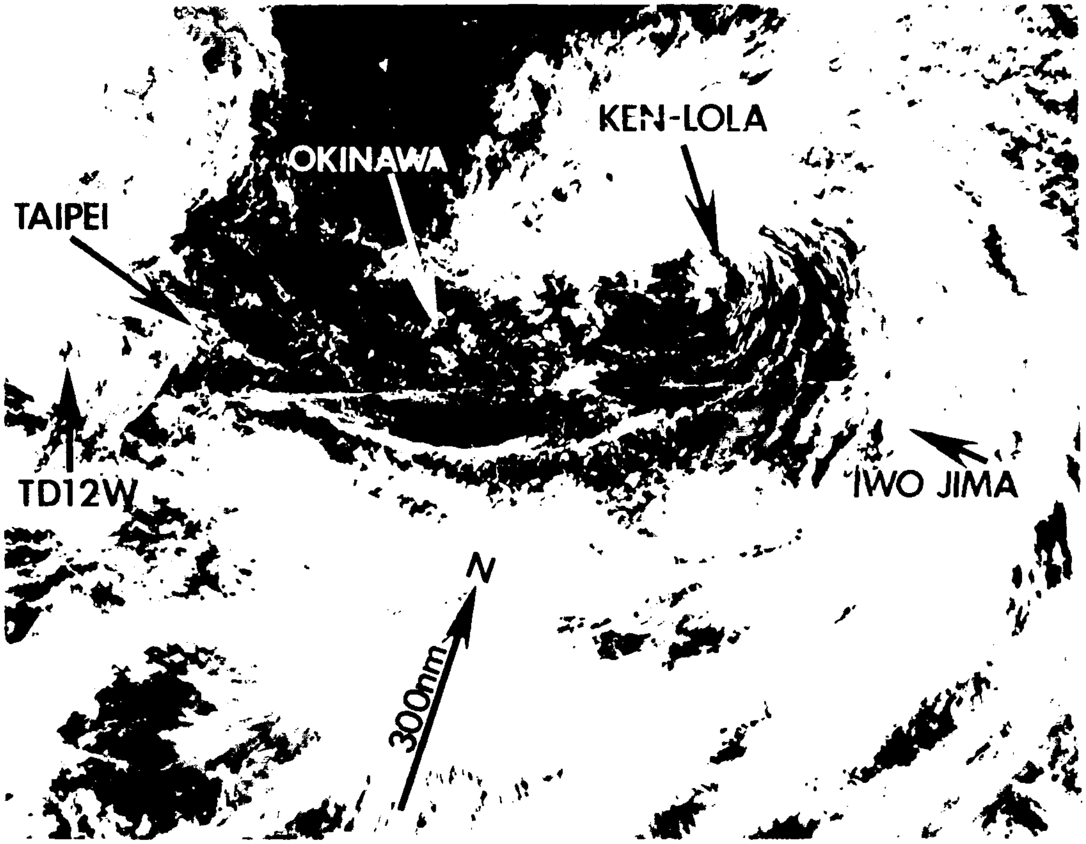


Figure 3-13-2. Imagery supporting the final warning on Tropical Storm Ken and formation of Lola. Note remnants of TD12W in the Taiwan Strait (310025Z July DMSP visual imagery).

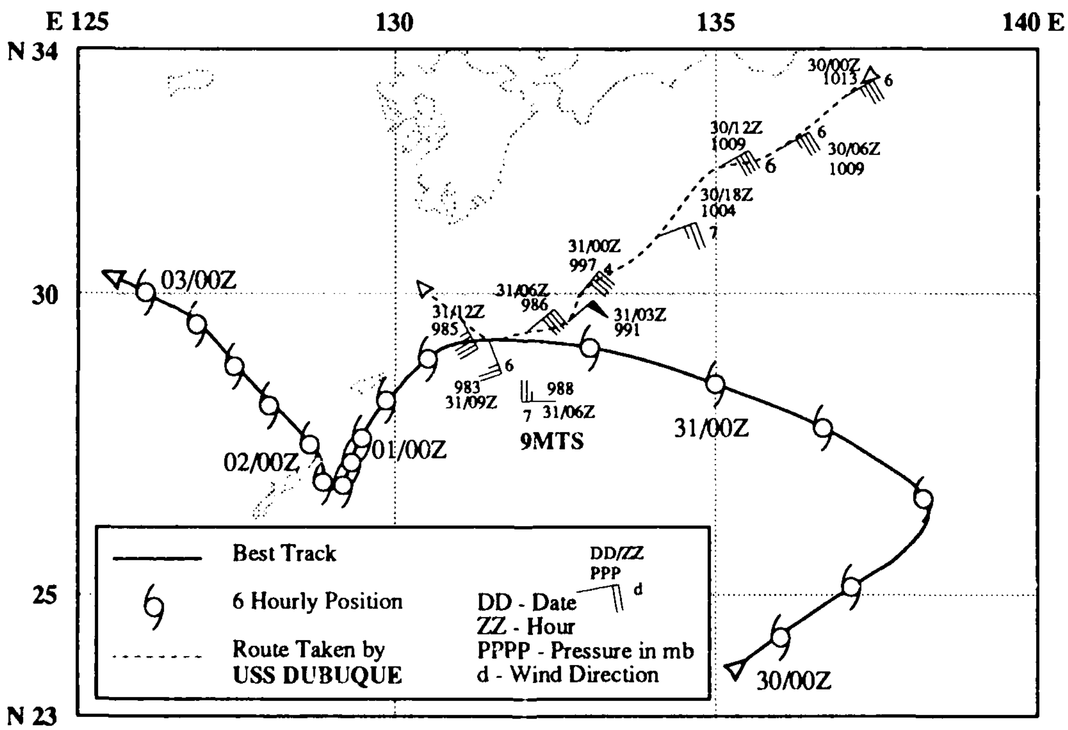


Figure 3-13-3. Wind and pressure reports from the USS **Dubuque** (LPD8) from 300000Z through 311200Z July with a report from ship **9MTS** at 310600Z help define the circulation center. Tropical storm symbols represent six-hourly best track positions for Tropical Storm Ken-Lola.

The first 72-hour forecast for Lola followed at 311200Z. The problems that aggravated this initial warning were the inconsistencies between fix platforms. Radar fixes were displaced to the west of the satellite fixes and suggested the system was moving rapidly southwestward. In contrast, the satellite fixes, based on cold cloud tops on infrared imagery, implied slow westward movement. Based on the prevailing northeasterly steering flow, the system was forecast to track west-southwestward and pass about 100 nm (185 km) northwest of Okinawa.

In a short time an understanding of the track became clearer. The radars were tracking a band of convection that was spiraling around the mid-level low. Also, the pressure at Kadena AB (WMO 47931) on Okinawa was not falling rapidly indicating Lola probably was not tracking rapidly to the southwest as had been suggested by the radar fixes. As a consequence, JTWC slowed the forecast speed of movement and angled the track towards Taiwan.

The mid-level cyclone appears to have been the major influence on Ken-Lola's track (Figure 3-13-4). In fact Ken-Lola's path described a elongated cycloid with the storm representing a point on the rotating "rim" of the westward moving 500 mb "wheel". The track made a cusp near Okinawa as the 500 mb center passed to the west of the system. The mid-level low pulled Ken-Lola northward and then westward into the East China Sea.

Kadena AB (WMO 47931) recorded peak winds of 30 kt (15 m/sec) as the system

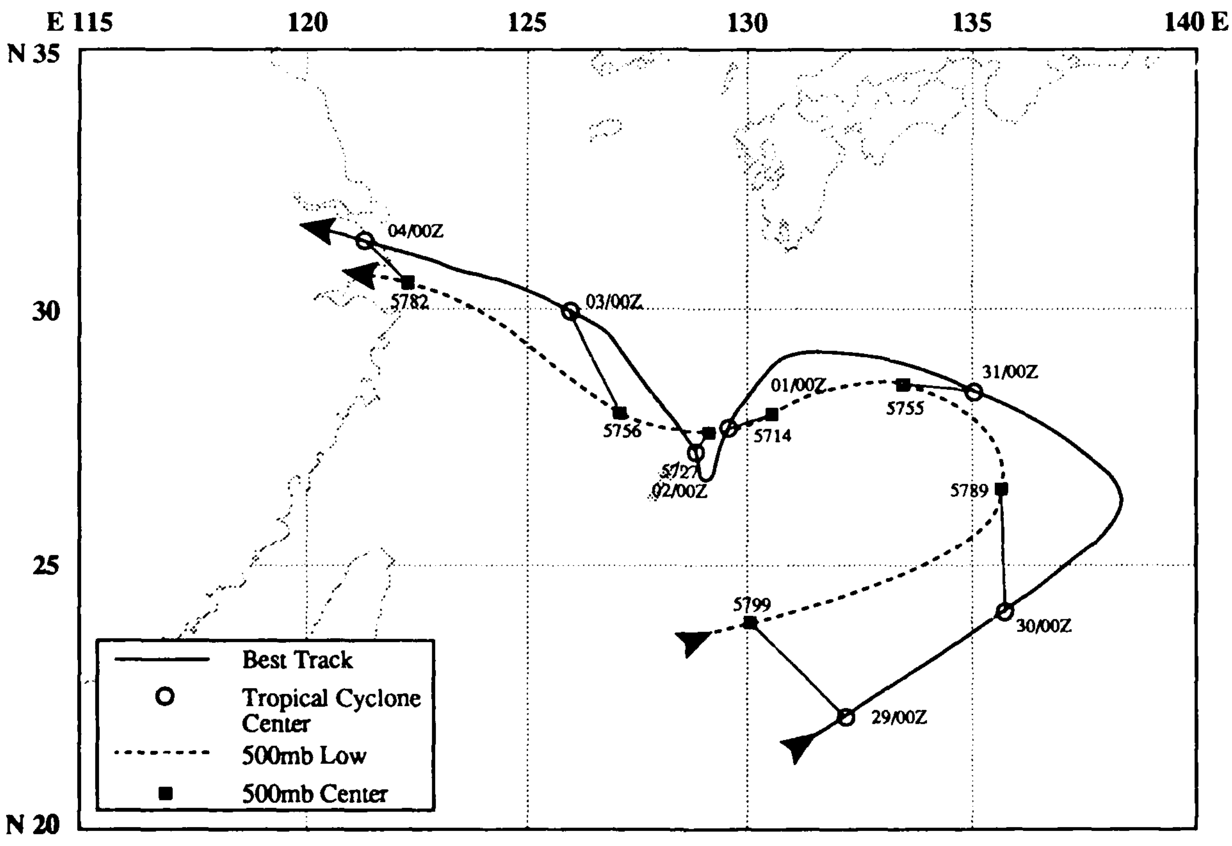


Figure 3-13-4. Spatial relationship between the tropical cyclone and accompanying 500 mb circulation center. Minimum 500 mb heights are in meters. Positions are for 0000Z from 29 July through 4 August.

passed within 80 nm (150 km) between 011800Z and 020000Z (Figure 3-13-5). The **USS Dubuque (LPD 8)**, which remained near Okinawa, reported 35-kt (18- m/sec) winds at 020600Z that decreased to 24 kt (12 m/sec) by 021200Z.

On 3 August, a building ridge over Manchuria caused Ken-Lola to take a more westward track toward Shanghai. Due to concern that a trough, approaching eastern China could reverse the tropical cyclone's track and take it northeastward into the Yellow Sea and Korea, the warnings continued until 041800Z when it was more than 250 nm (465 km) inland. The low relief and wetlands of the Yangtze River Valley allowed the weak circulation to maintain itself inland for several days. No reports of damage were received.

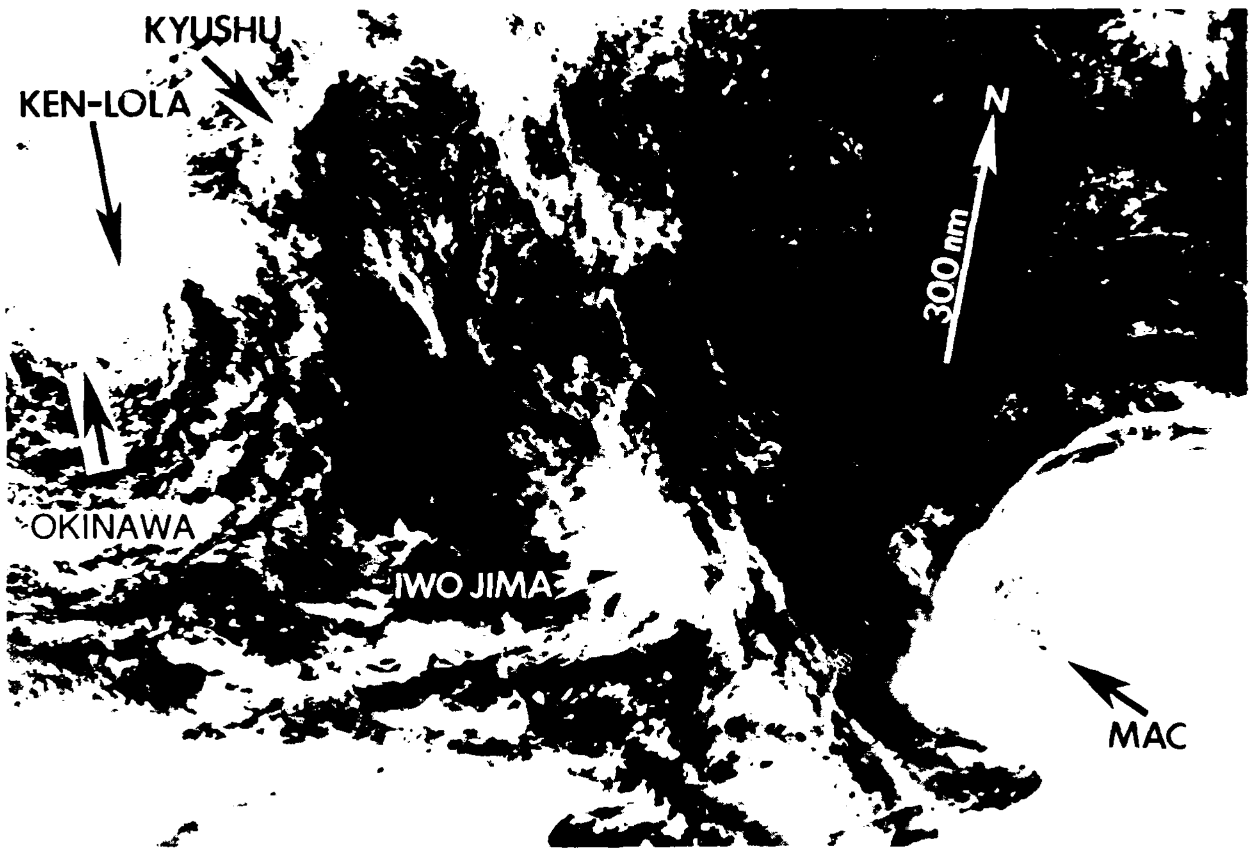
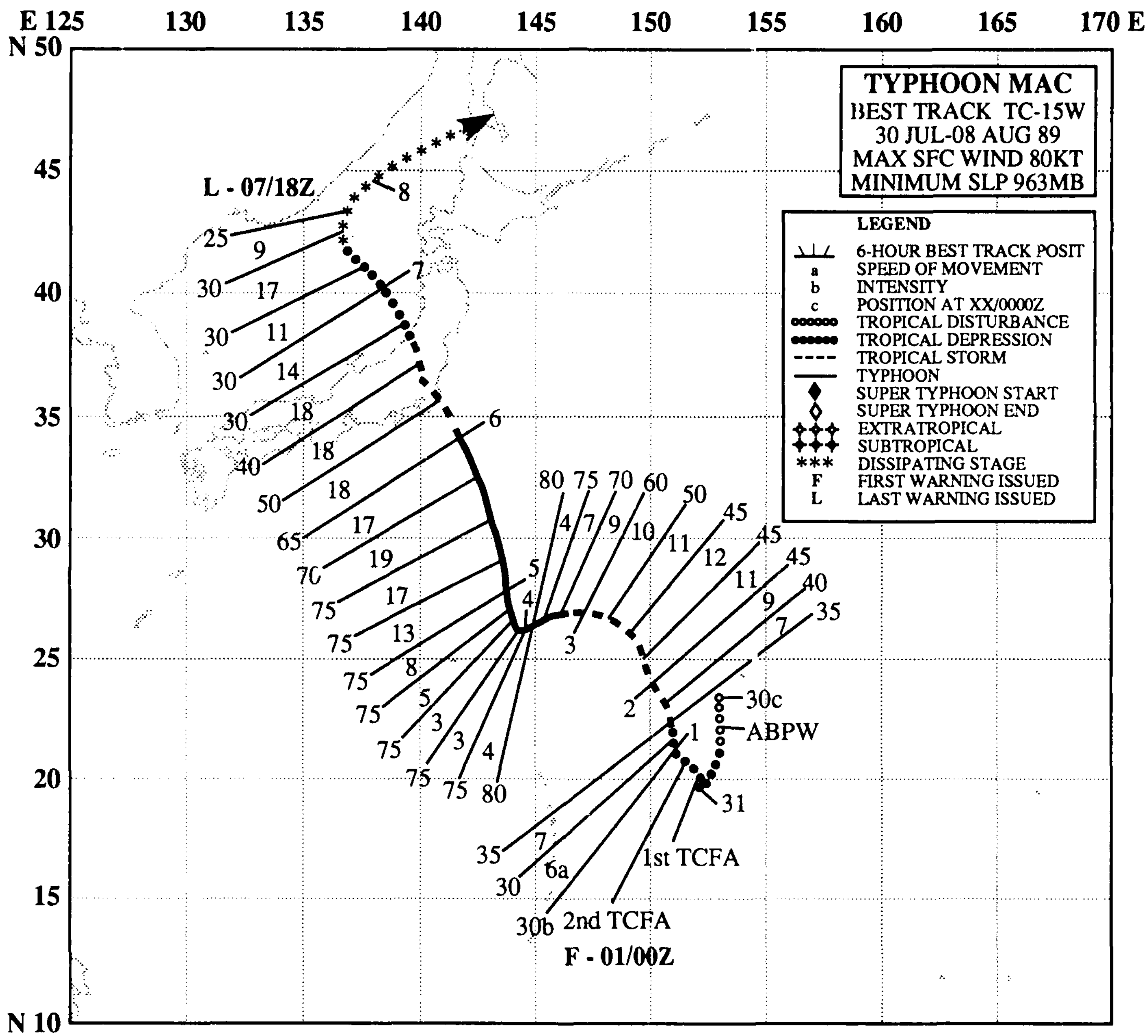


Figure 3-13-5. Ken-Lola nears Okinawa. Typhoon Mac (15W) is at the lower right (012344Z August DMSP visual imagery).


TYPHOON MAC
BEST TRACK TC-15W
30 JUL-08 AUG 89
MAX SFC WIND 80KT
MINIMUM SLP 963MB
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 07/18Z
F - 01/00Z
1st TCFA
2nd TCFA
ABPW
E 125
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140
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170 E
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N 10

TYPHOON MAC (15W)

The first typhoon of August, Mac developed at a higher than average latitude. Its track and intensity were influenced by a complex mid-latitude synoptic regime and complicated by a multi-storm environment. JTWC and NOGAPS had considerable difficulty distinguishing between short-term and long-term trends. Developing northeast of the Mariana Islands, Mac began with a general northwest track, moved westward 48 hours, then accelerated on a northwestward track and made landfall northeast of Tokyo. Mac weakened rapidly as it moved into and across the Sea of Japan, and finally dissipated over southern Sakhalin Island.

As the most active July since 1973 came to a close, Typhoon Judy (11W) was dissipating over Korea and Tropical Storm Ken-Lola (13W) was threatening Okinawa. At the same time, an area of convection developed approximately 600 nm (1111 km) northeast of Saipan in an extremely active monsoon trough that extended as far east as Wake Island. The 300000Z July surface analysis indicated that a low-level cyclonic circulation with a 1008 mb pressure was associated with an area of disturbed weather. JTWC classified the disturbance as having poor potential for further development on the 300600Z Significant Tropical Weather Advisory. Subsequent synoptic reports indicated that the central pressure had decreased to 1006 mb and surface winds had increased. Thus, JTWC reissued the Significant Tropical Weather Advisory at 301000Z to upgrade the disturbance's potential to fair.

The disturbance's central convection increased and additional synoptic reports indicated that the central pressure had fallen to

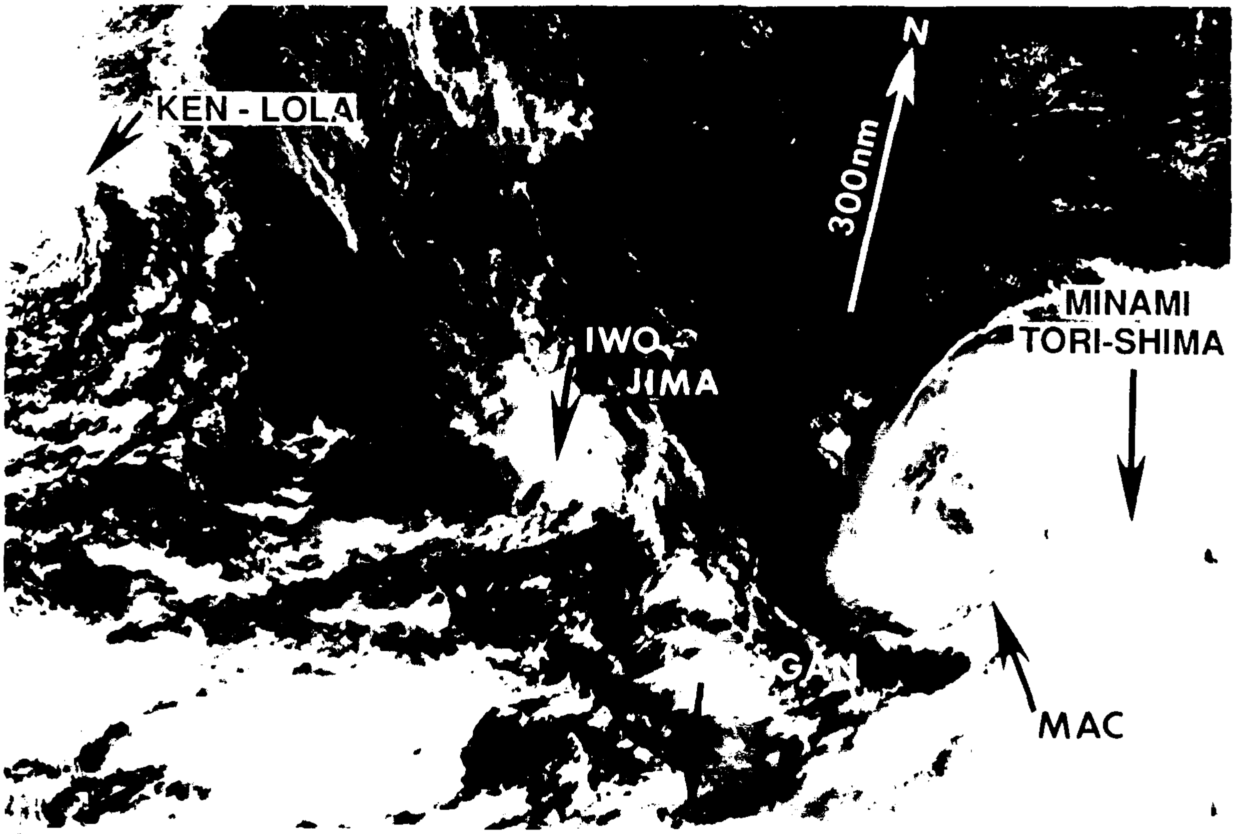

Figure 3-15-1. Mac's cirrus outflow (at left) is impressive compared to Ken-Lola (13W-14W) (012344Z August DMSP visual imagery).

1000 mb. The surface winds north of the system were 20 to 25 kt (10 to 13 m/sec) and monsoon gales were present to the south. JTWC issued a Tropical Cyclone Formation Alert at 310400Z with the disturbance moving to the southeast. Subsequent fix information indicated that the disturbance had actually made a cyclonic loop and was moving northwestward out of the Alert area. In response, JTWC reissued the Alert at 311700Z.

While the first warning on Tropical Storm Mac was issued at 010000Z August, post-analysis indicated that the system did not reach tropical storm intensity until 12 hours later. The first series of forecasts called for Mac to track northward along the 150° east meridian. Due to the mid-tropospheric subtropical high weakening, the early stages of the forecasts verified well — as Mac tracked north-northwestward for the next 36 hours.

While Tropical Storm Ken-Lola (13W-14W) was in the vicinity of Okinawa on 2 August, JTWC changed its forecast outlook on Mac (Figure 3-15-1). The 020600Z warning had Mac moving westward along 30° north latitude in the 48- to 72-hour period as a complex series of events began to unfold. At the same time as a long-wave trough moved

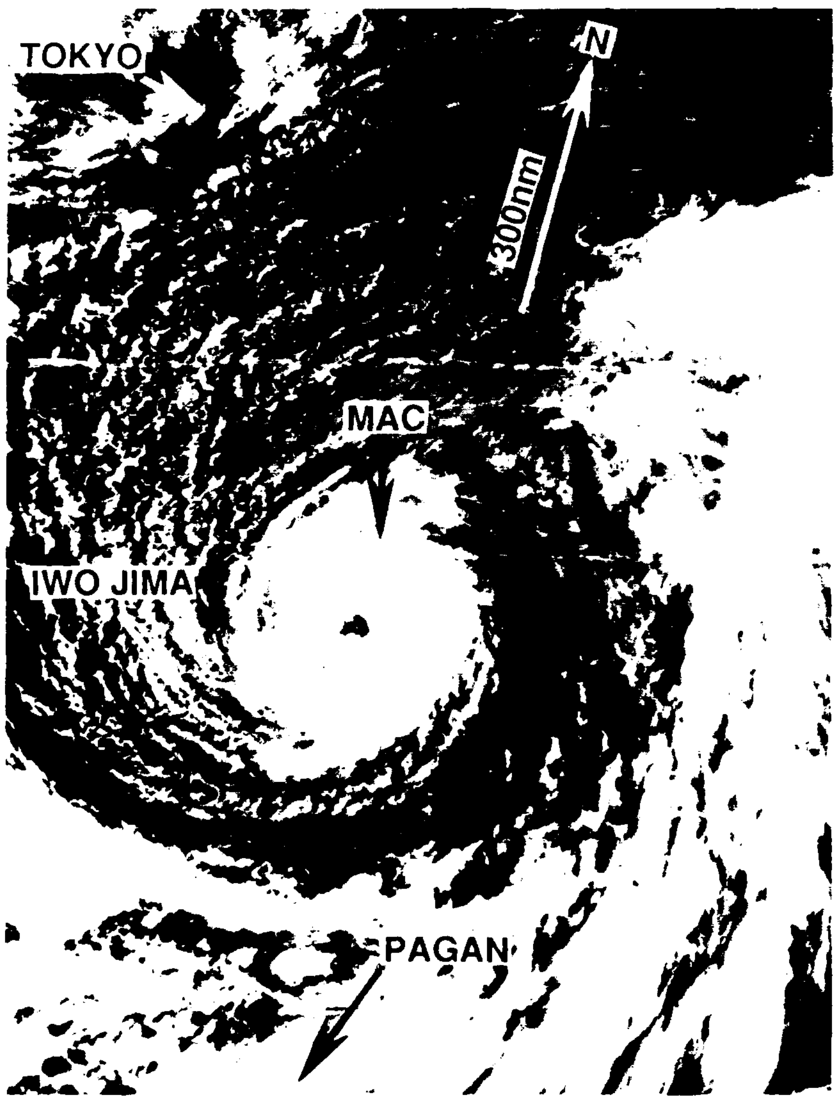

Figure 3-15-2. At peak intensity, Mac is surrounded by a ring of subsidence (032304Z August DMSP visual imagery).

eastward into the Sea of Japan, a large TUTT cyclone began to tumble rapidly westward from the date line. While the TUTT cell moved northwest of Mac, the mid-tropospheric subtropical ridge strengthened, placing Mac under the influence of easterly flow. This was similar to events that had recently forced Typhoon Judy (11W) to move westward. JTWC would remain with the westward track along 30° north latitude for the next nine warnings.

The westward movement began much earlier than forecast, in fact, along 27° instead of 30° north latitude and within 12 hours instead of 48 hours. Mac continued the westward movement for the next 48 hours reaching typhoon intensity at 030300Z. JTWC had high confidence in its forecast as NOGAPS built a high over the Sea of Japan and most of the objective techniques supported slow westward movement. Confidence was further heightened when Mac began tracking west-southwestward at 030000Z. JTWC forecasters recognized the unfavorable upper-level regime and displayed great success with the intensity forecasts. Mac reached its peak intensity of 80 kt (41 m/sec) at 031800Z (Figure 3-15-2).

During its westward track, an ominous slowing of Mac's forward speed occurred. At 040600Z Mac was moving very slowly west-southwestward. The 040000Z analysis indicated that a jet maximum approaching the trough axis which could deepen the trough. The Prognostic Reasoning accompanying the 040600Z warning did mention recurvature as a low-probability alternate scenario. JTWC's westward scenario was reinforced by the movement of a high from Mongolia to coastal Manchuria. Forecasters thought the continued eastward movement of that high and Mac's westward movement would allow the typhoon to escape the influence of the digging trough as ridging reestablished itself to Mac's north.

In the meantime, the TUTT cell that had tumbled westward slowed down and linked up with the mid-latitude trough in the Sea of Japan. This blocked significant eastward movement of the high over Manchuria and changed Mac's steering flow from westward to northward around the east side of the the TUTT cell. JTWC added northward movement to the Prognostic Reasoning accompanying that 041200Z warning as a moderate probability alternate scenario. At 041800Z, the westward forecast was abandoned as Mac made a slow move northward and the new 041200Z NOGAPS no longer showed the high building over the Sea of Japan. JTWC swung the forecast track to the northwest toward Osaka near the 72-hour point. JTWC remained with that forecast for the next two warnings.

Meanwhile Mac had accelerated from 3 kt (6 km/hr) at 041200Z to 13 kt (24 km/hr) toward the north-northwest at 050600Z as it ran along the east side of the TUTT cell. The TUTT cell was expected to resume its normal southwestward movement causing Mac to resume a northwestward track toward Osaka. This reasoning was reinforced by height falls occurring ***west*** of Tokyo.

By 051200Z, Mac had accelerated to 17 kt (32 km/hr). At this time, JTWC shifted the forecast track to pass 180 nm (335 km) ***east*** of Tokyo within 24 hours. Satellite fixes indicated a northward movement and subsequent radar observations from Tori-Shima (WMO 47639) confirmed the north-northwestward track. In addition, the TUTT cell and an upper-level low over the northern Sea of Japan linked producing an extended trough. Mac would now maintain a forward speed of 17 kt (32 km/hr), or more, during the next 30 hours.

After 051800Z, Mac shifted from a north-northwestward course to a more north-westward course, as the tough in the Sea of

Japan began to weaken. Mac finally passed ***east*** of Tokyo at 060700Z, but only by 60 nm (111 km) with an intensity of 45 kt (23 m/sec) (Figure 3-15-3). The tropical cyclone made landfall at 061000Z. At 061200Z, Mac was downgraded to tropical storm intensity, however, post-analysis indicates Mac was a tropical storm at least six hours earlier.

Mac weakened while crossing Japan, but without the benefit of satellite intensity analysis and availability of continuous observations, JTWC conservatively maintained Mac at tropical storm intensity until 070600Z. MAC actually entered the Sea of Japan, near Sakata, as a tropical depression at 061700Z. The final warning on Tropical Depression 15W was issued at 071800Z. The remnants turned northeastward and dissipated over southern Sakhalin island on 8 August.

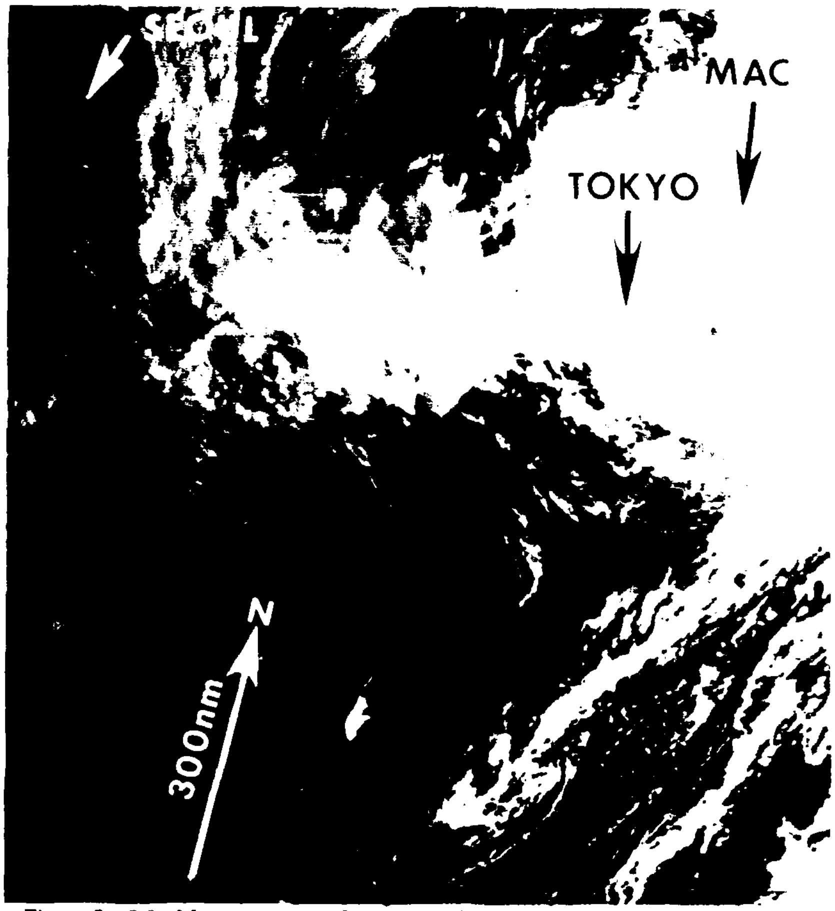

Figure 3-15-3. Mac approaches Japan (060438Z August NOAA visual imagery).

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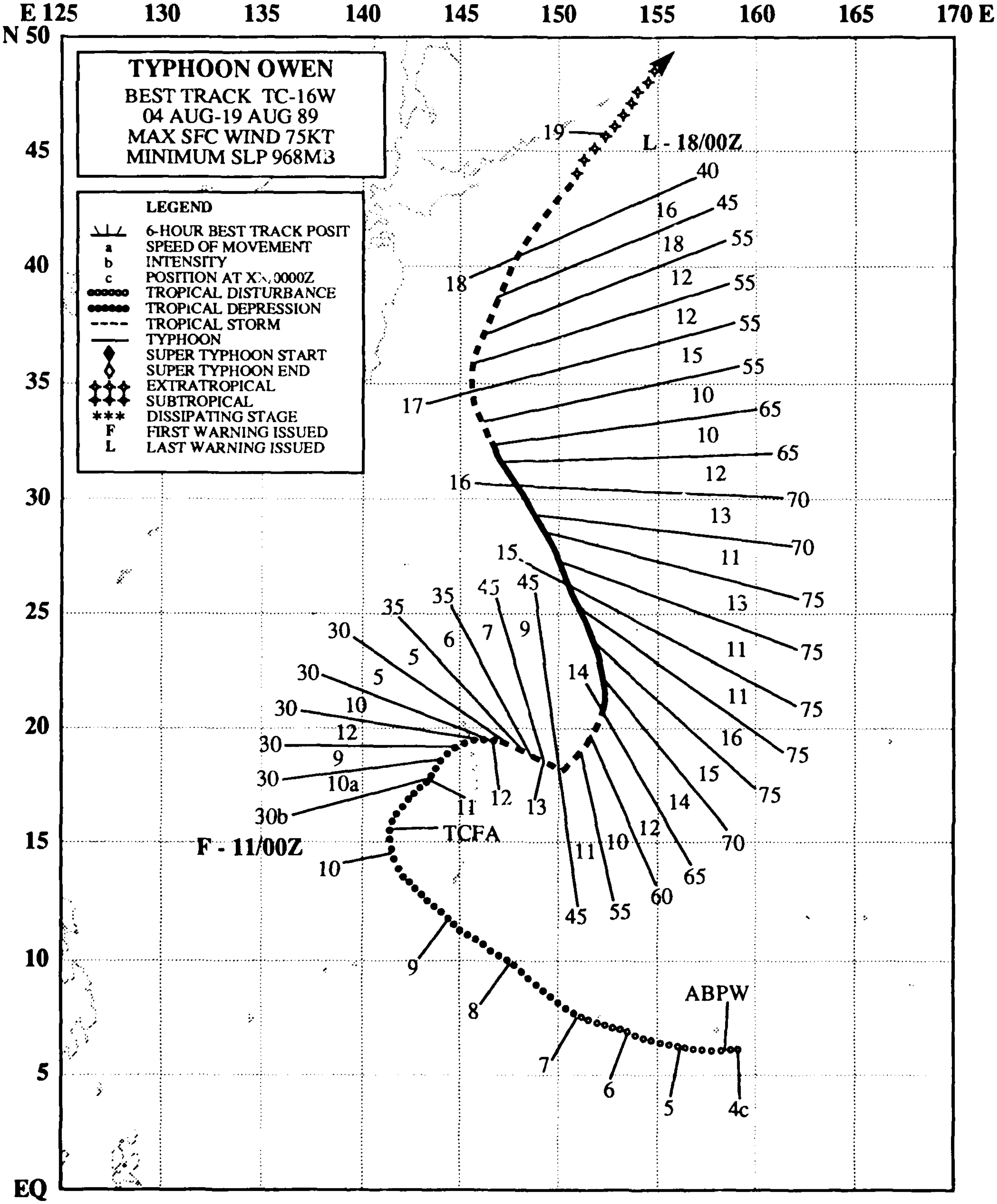

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EQ
TYPHOON OWEN
BEST TRACK TC-16W
04 AUG-19 AUG 89
MAX SFC WIND 75KT
MINIMUM SLP 968MB
LEGEND
6-HOUR BEST TRACK POSIT
SPEED OF MOVEMENT
INTENSITY
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
L - 18/00Z
F - 11/00Z
TCFA
ABPW

TYPHOON OWEN (16W)

Typhoon Owen generated in the monsoon trough and intensified slowly while moving on a general northwest to northward track. Due to the proximity* of Typhoon Nancy (17W) to the east, Owen took more than a week to reach tropical storm intensity. Later, its binary interaction with Typhoon Nancy (17W) resulted in an unusual southeastward track during its developing stage. Then, the tropical cyclone followed Nancy (17W) through recurvature, extratropical transition and into high latitudes.

The initial disturbance that spawned Typhoon Owen began as an area of convection in the monsoon trough south of Pohnpei in the eastern Caroline Islands. After the convection persisted for 24 hours, JTWC included the disturbance as a suspect area on the Significant Tropical Weather Advisory at 040600Z. Synoptic data indicated a weak low-level circulation under easterly flow aloft. During the next six days, the amount and organization of the convection associated with the disturbance fluctuated as the monsoon trough repositioned further north. Finally convection consolidated beneath an upper-level anticyclone, prompting JTWC to issue a Tropical Cyclone Formation Alert at 100600Z.

* If formative tropical cyclones are separated by distances of less than fifteen degrees, interaction (at the expense of one, or the other) between the two circulations is often observed.

During the next 18 hours, the system continued to organize, although its upper-level outflow was restricted by a TUTT cell centered four to five degrees latitude to the north-northwest. At 110000Z, JTWC issued a 36 hour tropical depression warning on Tropical Depression 16W and forecast no intensification because of its proximity to the TUTT cell. The tropical cyclone tracked northeastward along the monsoon trough axis and through the northern Mariana Islands for the next 18 hours, influenced both by the TUTT cell and by Tropical Depression 17W. By 120000Z, a well-defined upper-level anticyclone had established itself over Owen, and the system improved its organization and convection. Anticipating further intensification, JTWC transitioned to a regular 72-hour warning. At 121200Z, the depression reached tropical storm intensity based on satellite intensity estimates. By this time, a binary interaction with Nancy (17W) was beginning to influence Owen's track and resulting in a slow southeastward movement until 131200Z. (For specific diagrams of this binary interaction, please see the following article on Typhoon Nancy (17W).) Owen became a typhoon at 131800Z and reached its peak intensity of 75 kt (38 m/sec) at 141200Z.

As Owen followed Nancy (17W) to the north-northwest, the recently formed eye began to fill (Figure 3-16-1). With the subtropical ridge close by, at 161500Z, Owen weakened to tropical storm intensity and began to be buffeted by upper-level westerly flow. Twelve hours later Owen recurved around the ridge and accelerated to the northeast. At 180000Z, JTWC issued its final warning on Owen as it crossed 40° north latitude and was becoming extratropical. During its lifetime, Owen was a threat primarily to maritime interests. No reports of damage or loss of life were received.

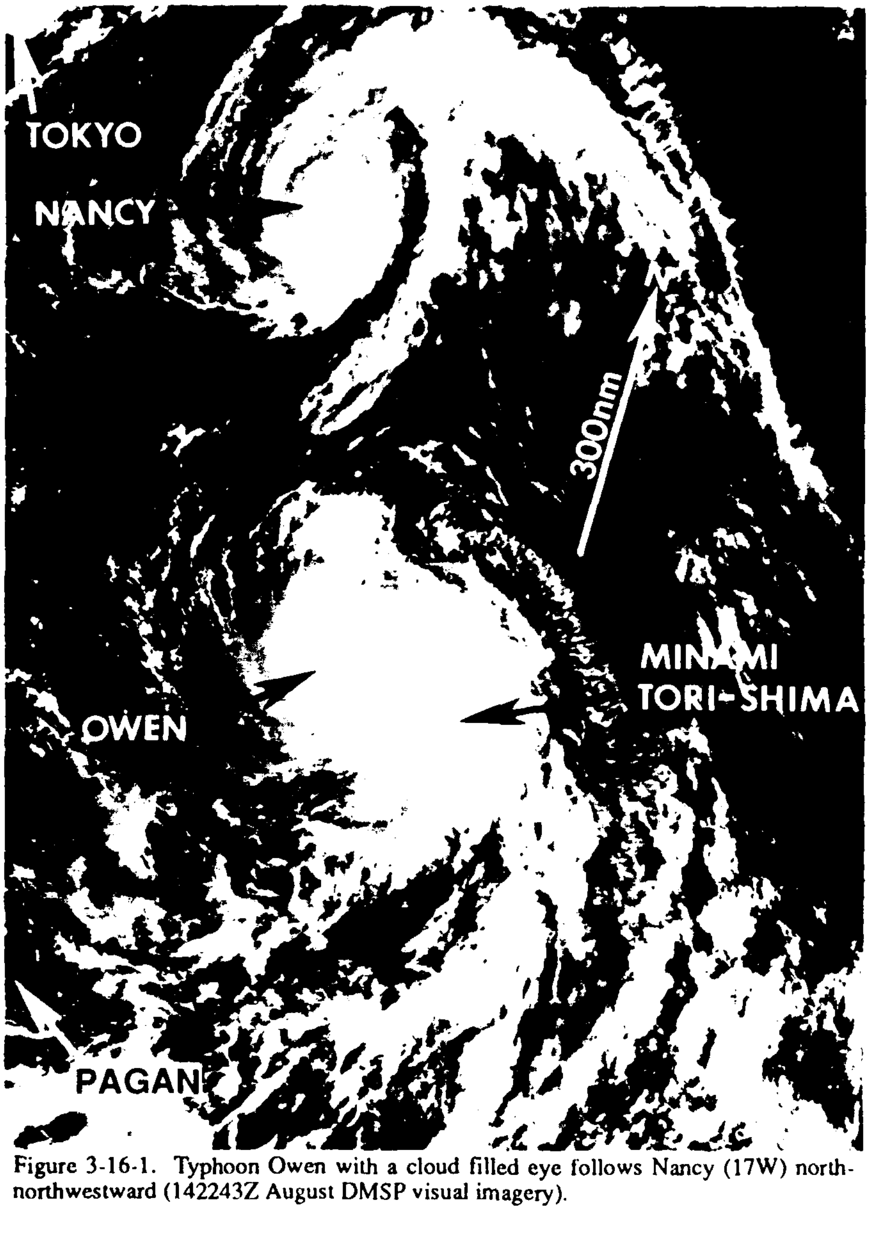

Figure 3-16-1. Typhoon Owen with a cloud filled eye follows Nancy (17W) north-northwestward (142243Z August DMSP visual imagery).

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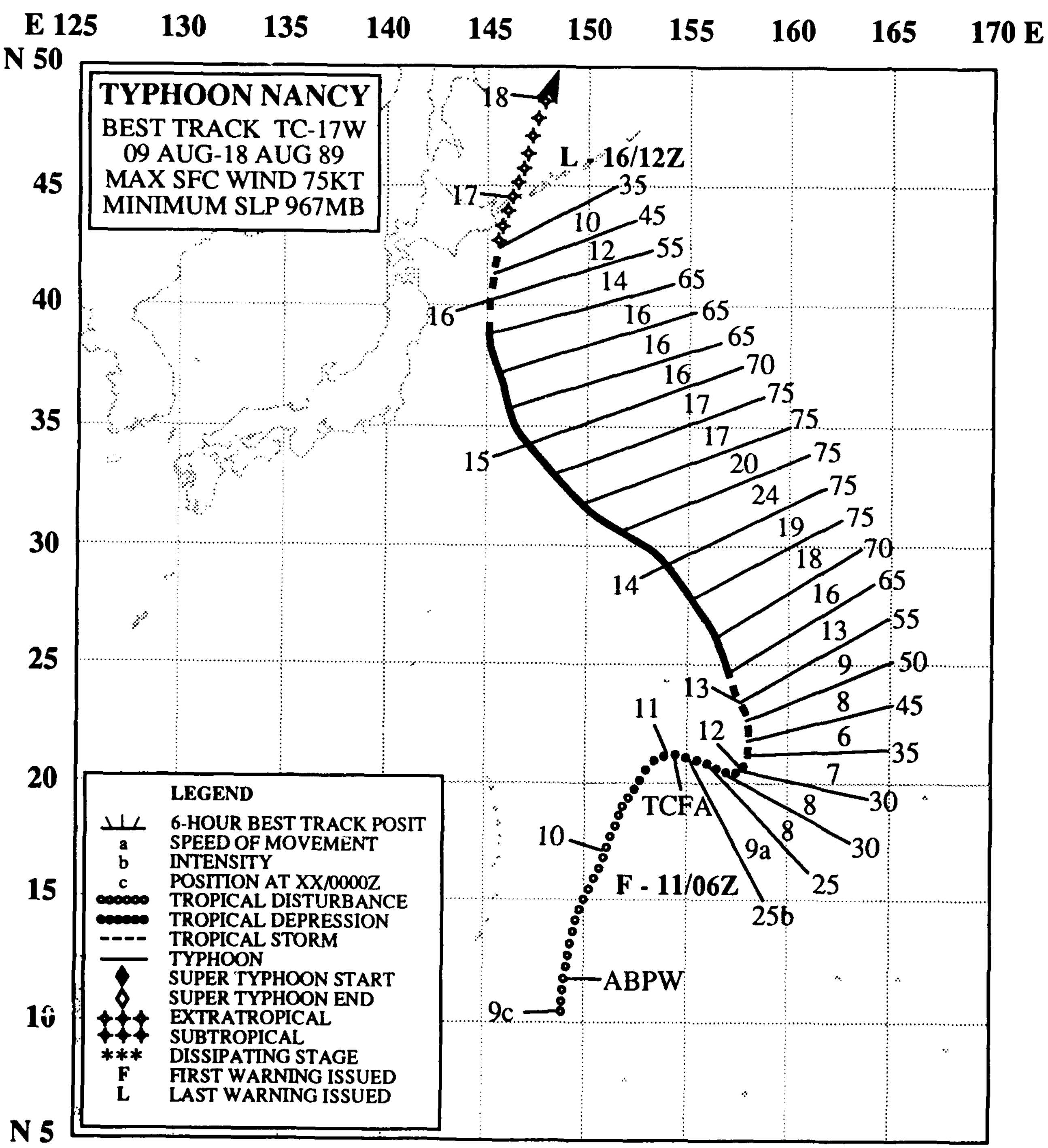


TYPHOON NANCY
BEST TRACK TC-17W
09 AUG-18 AUG 89
MAX SFC WIND 75KT
MINIMUM SLP 967MB
E 125
130
135
140
145
150
155
160
165
170 E
N 50
45
40
35
30
25
20
15
10
N 5
L - 16/12Z
F - 11/06Z
TCFA
ABPW
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TYPHOON NANCY (17W)

Of the eight August tropical cyclones, Nancy was the third typhoon. It underwent a prolonged binary interaction with Typhoon Owen (16W), tracked rapidly toward Japan, then abruptly turned northward, and finally became extratropical.

The disturbance that eventually became Typhoon Nancy appeared as an area of persistent convection in the monsoon trough. It was first considered as a suspect area on the 9 August Significant Tropical Weather Advisory. The disturbance tracked northeastward in response to surging monsoon southwesterlies. At 110100Z, JTWC issued a Tropical Cyclone Formation Alert based on increased curvature in the convective bands and a cyclonic tumbling motion of the convection on animated satellite imagery. The first warning for Tropical Depression 17W followed at 110600Z when satellite imagery revealed a developing central dense overcast. At first, JTWC forecast Tropical Depression 17W to make a curve to the north and then track northwestward, as it separated from the monsoon trough and interacted with the subtropical ridge which was building westward. The system did, indeed, follow the forecast, however, only after an unforecast 18-hour jog to the southeast. During this early stage, both Tropical Depressions 17W and 16W competed for low-level inflow and favorable upper-level outflow channels, causing

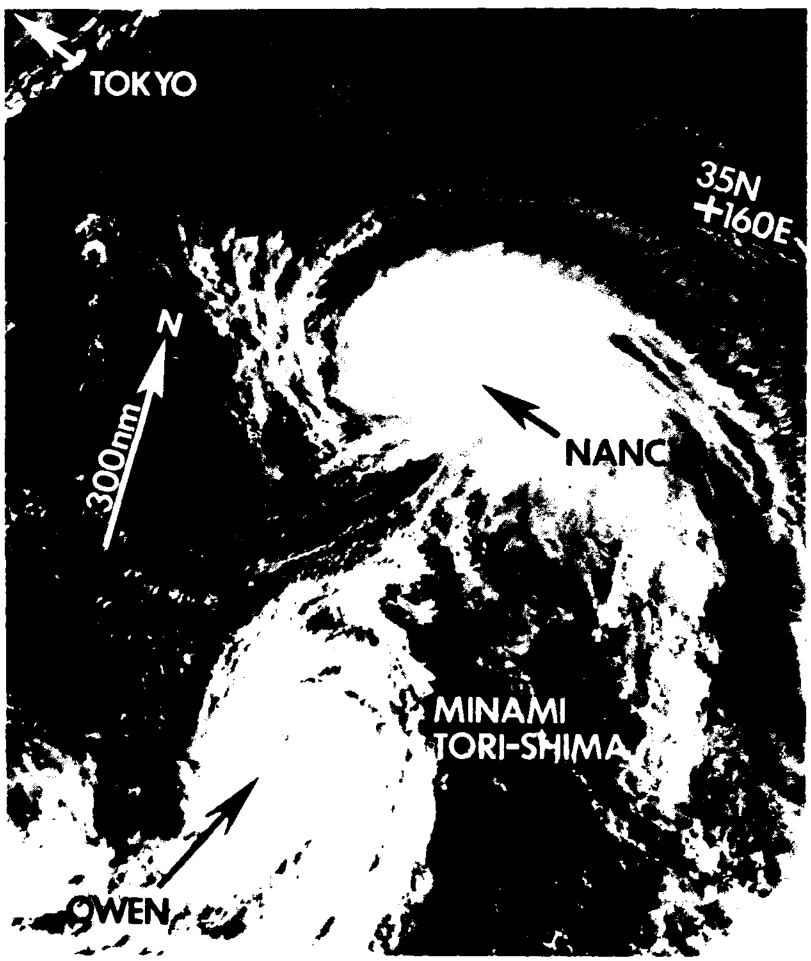


Figure 3-17-1. Typhoons Nancy and Owen (16W) at peak intensity (140313Z August NOAA infrared imagery).

a high degree of uncertainty as to which system would dominate.

As Tropical Depression 17W turned to the north, it was upgraded to Tropical Storm Nancy at 120600Z. Six hours later, Tropical Depression 16W also would become a tropical storm. Then, Nancy broke free of the monsoon trough and began rapid intensification, reaching typhoon intensity within 24 hours of its upgrade to a tropical storm.

JTWC anticipated the possibility of binary interaction with Tropical Depression 16W as soon as Nancy formed. While Tropical Depression 16W intensified, the two systems closed to within 600 nm (1110 km) of each other, and binary interaction became evident when Nancy turned northward. Nancy and Owen (16W) rotated around each other from 120000Z until 150000Z (Figure 3-17-1), an exceptionally long period. The rotation between the two systems about a common center point totaled 105 degrees. During this time, Nancy accelerated from 6 kt (11 km/hr) on 12 August to 24 kt (44 km/hr) on 14 August in response to the combined effects of increased steering flow and the interaction with Owen (16W). A comparison of both typhoon tracks referenced to the center of motion, or centroid, is shown in Figure 3-17-2. The centroid's track (Figure 3-17-3) during the binary interaction moved east and then turned to the northwest. JTWC used this as a forecast aid for both cyclones, with good results. JTWC propagated the centroid northward, however, results would have been even better had JTWC steered the centroid with the north-northwestward steering flow. At 131800Z, Nancy reached a peak intensity of 75 kt (39 m/sec) and started accelerating towards Tokyo, a track that would reach the metropolis in 24 hours. Based on the expected behavior from the binary interaction, JTWC forecasters projected the cyclone to slow down and veer to the north. Twelve hours later, the forecast motion away from Japan

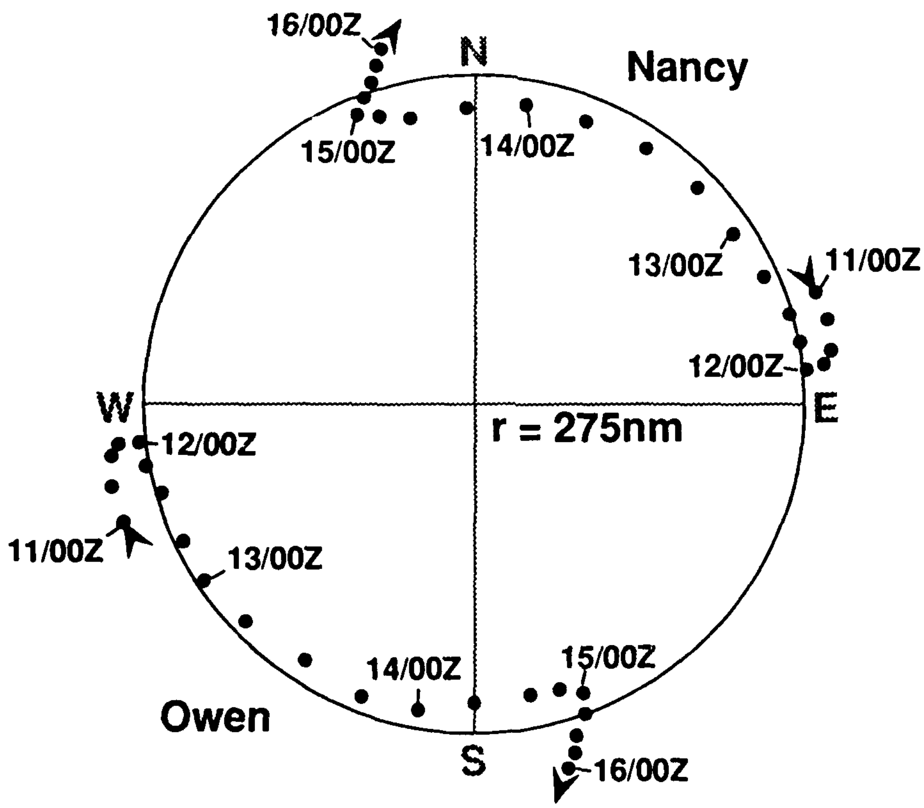


Figure 3-17-2. Tracks of Typhoons Nancy and Owen (16W) relative to their common center. Binary interaction lasted for 72 hours and through 105 degrees of rotation.

materialized. On 15 August, the binary interaction between Nancy and Owen (16W) ended abruptly. There is, to our knowledge, no research that indicates when a binary interaction will cease and the storms will resume independent tracks.

In retrospect, and in light of a similar north-orientated track of Typhoon Mac (15W) two weeks before, there was concern whether Nancy would cross over Japan. But, the NOGAPS prognostic series were quite consistent in moving a trough, which could induce recurvature, to the east of Japan. The series also built a mid-tropospheric ridge that would stop any further northwest movement over the northern Sea of Japan. At 160000Z, Nancy was moving north of the mid-tropospheric subtropical ridge. It had weakened to tropical storm intensity, and began extratropical transition. Without deep convection to maintain the warm core, the cyclone completed its extratropical transition. The final warning was issued at 161200Z as the low level circulation center tracked north-northeastward just east of Hokkaido.

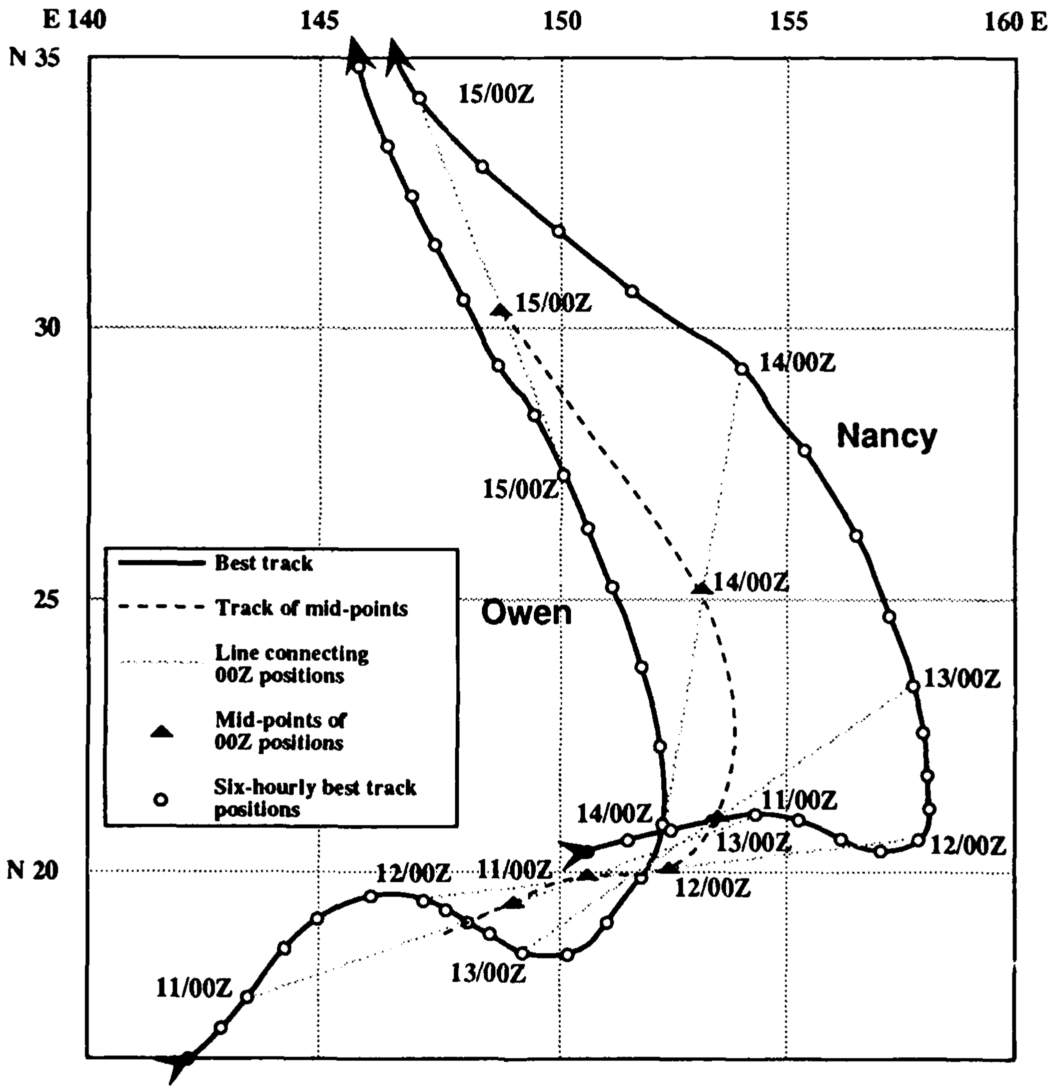
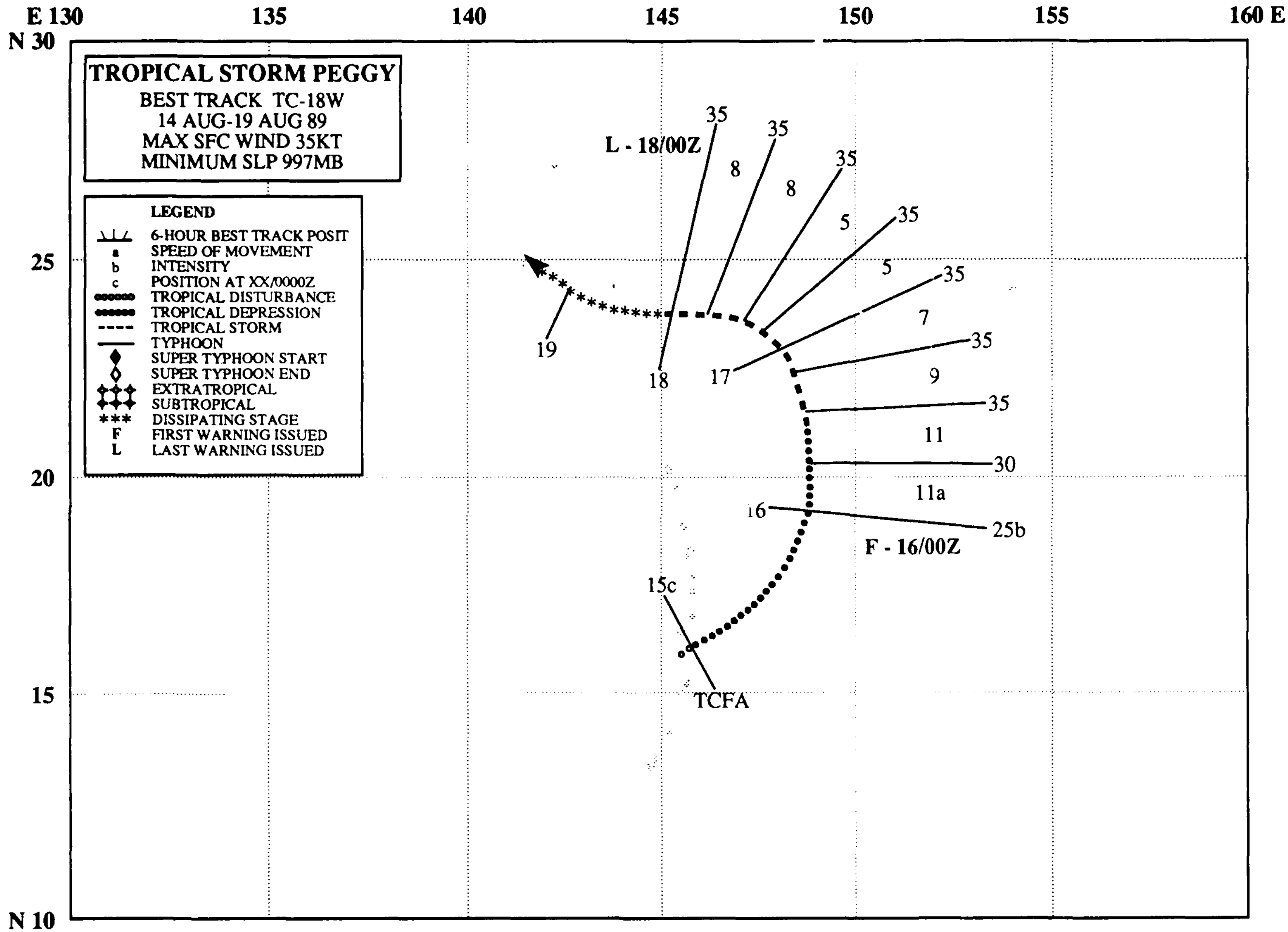


Figure 3-17-3. Path of mid-points between Typhoons Nancy and Owen (16W).


TROPICAL STORM PEGGY
BEST TRACK TC-18W
14 AUG-19 AUG 89
MAX SFC WIND 35KT
MINIMUM SLP 997MB
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 130
135
140
145
150
155
160 E
N 30
25
20
15
N 10
L - 18/00Z
F - 16/00Z
TCFA
15c
16
17
18
19
25b
11a
30
11
35
9
7
5
8

TROPICAL STORM PEGGY (18W)

The third tropical cyclone to develop in the monsoon trough between 11 and 16 August, Peggy was short-lived and only reached minimal tropical storm intensity.

While tropical cyclones Owen (16W) and Nancy (17W) were completing their binary interaction and moving northward, the disturbance that would eventually become Peggy formed in the monsoon trough roughly 200 nm (370 km) north of Guam. Late on 14 August, satellite imagery displayed a new area of convection associated with a low-level circulation center. After sparse synoptic data indicated falling pressures and wind shifts reflected the circulation's development, JTWC issued a Tropical Cyclone Formation Alert at 150000Z.

Initially, the disturbance moved northeastward and a small ragged area of central convection persisted. This persistent, but small, central dense overcast led JTWC to issue the first warning on Tropical Depression 18W at 160000Z. The depression then turned north to follow Owen's (16W) track. Increased convection resulted in an upgrade to tropical storm intensity on the 161200Z warning. The outflow from Owen (16W) restricted Peggy's outflow aloft. This increased vertical shear, in combination with the subsidence associated with a Tropical Upper Tropospheric Trough (TUTT) cell to the northeast, kept Peggy from developing further. Minor flare-ups of convection were, however, sufficient to allow Peggy to maintain its 35-kt (18 m/sec) intensity despite the shear. Meanwhile, lower tropospheric ridging northeast of Peggy caused the cyclone to turn to the west. At 180000Z, the final warning was issued when satellite imagery (Figure 3-18-1) indicated the separation of the low-level circulation from its convection and that the low-level center would remain in an area of strong subsidence. The residual low-level vorticity center drifted west-northwestward and dissipated on 19 August near Iwo Jima.

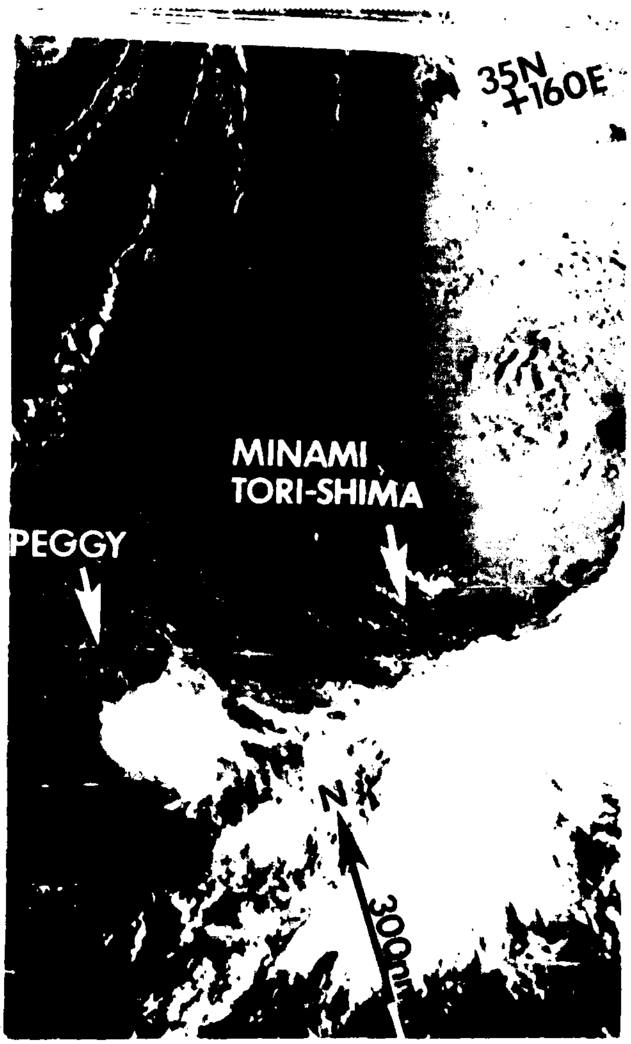
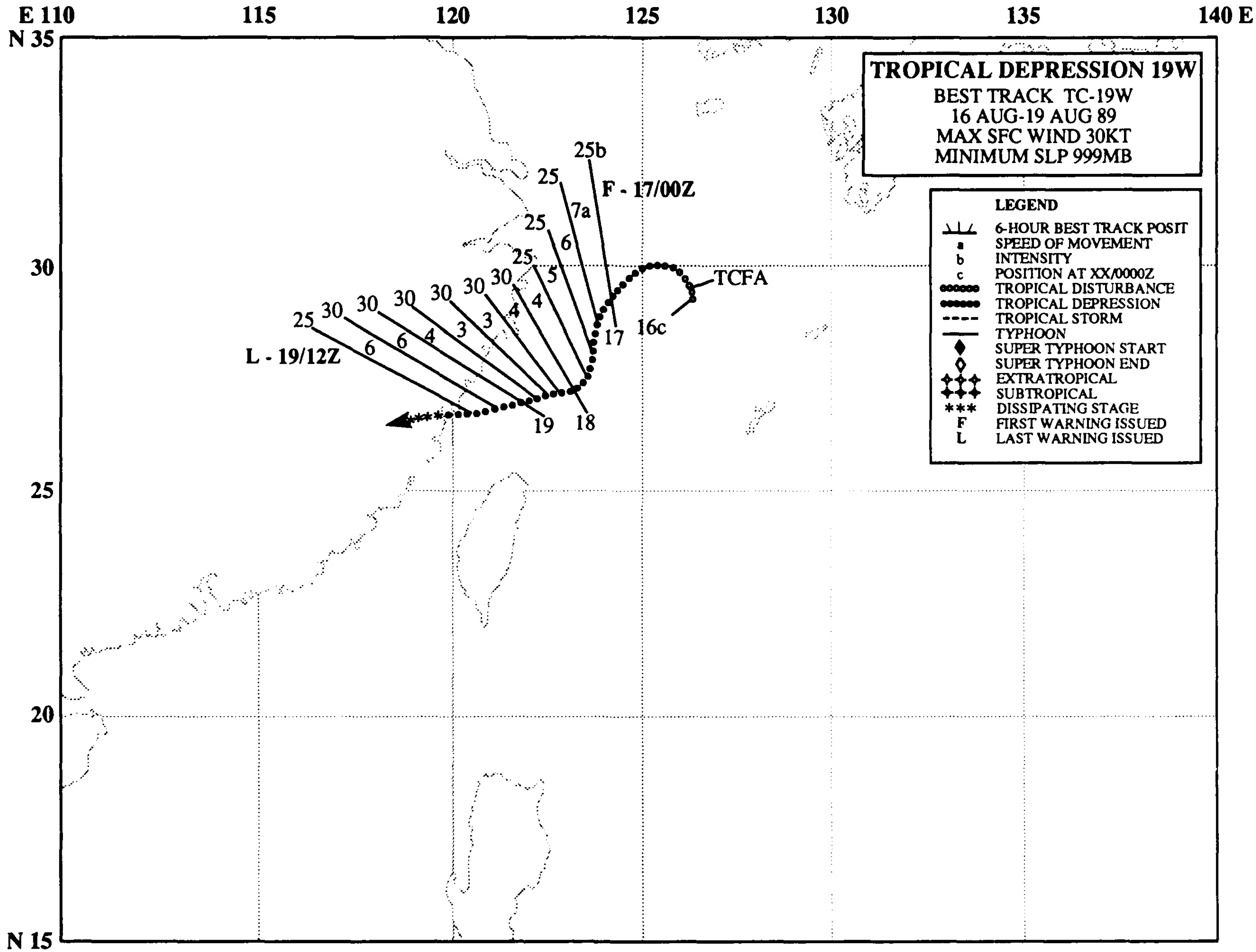


Figure 3-18-1. Vertical wind shear from the northwest exposes the low-level circulation center as a TUTT cell to the northeast of Peggy is becomes the dominant feature (172206Z August NOAA visual imagery).



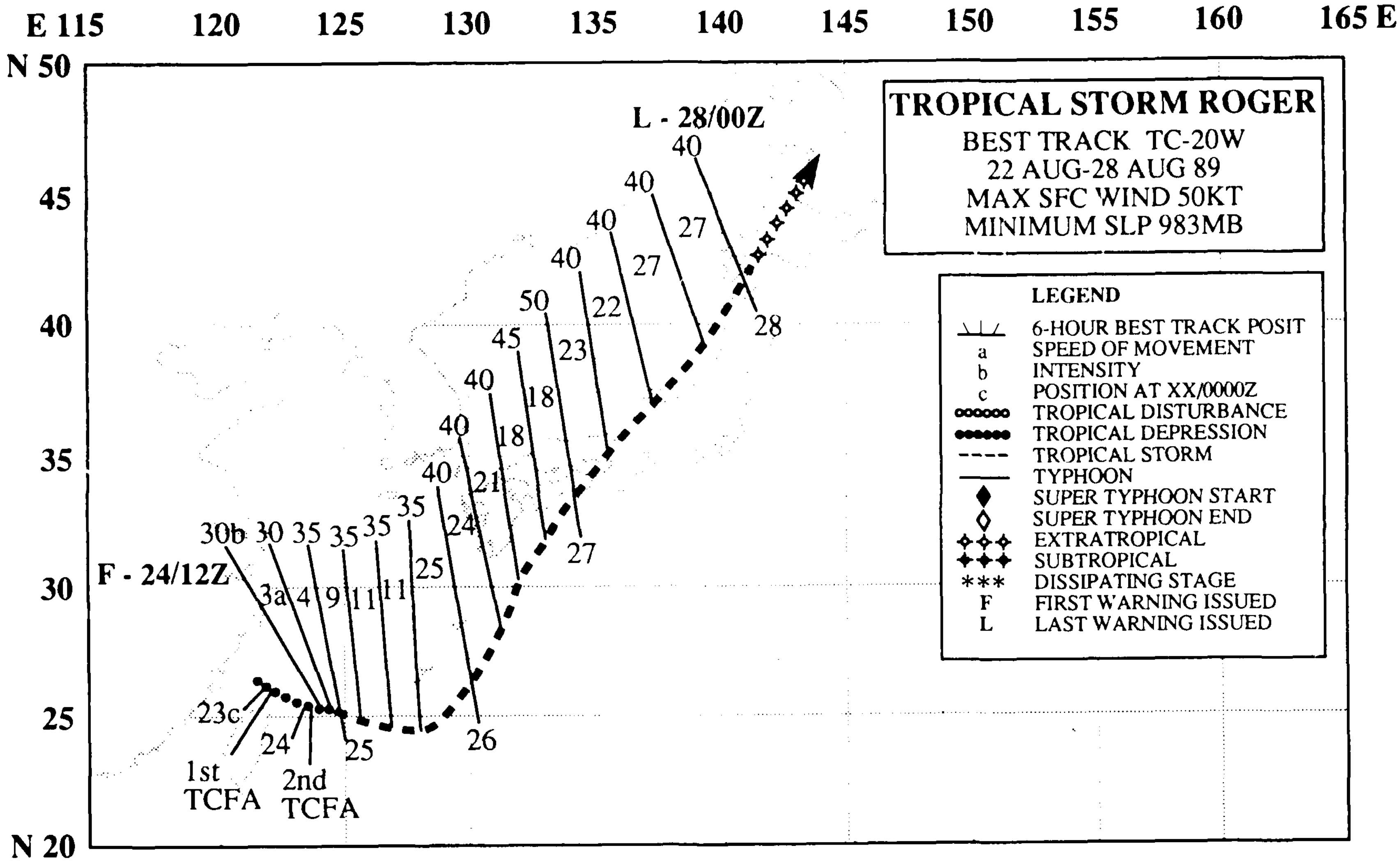
TROPICAL DEPRESSION 19W
BEST TRACK TC-19W
16 AUG-19 AUG 89
MAX SFC WIND 30KT
MINIMUM SLP 999MB
LEGEND
6-HOUR BEST TRACK POSIT
SPEED OF MOVEMENT
INTENSITY
POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
E 110
115
120
125
130
135
140 E
N 35
30
25
20
N 15
F - 17/00Z
L - 19/12Z
TCFA
16c
17
18
19
25b
7a

TROPICAL DEPRESSION 19W

Developing from a large area of low pressure and disturbed weather, this system was first detected on satellite imagery approximately 180 nm (335 km) northwest of Okinawa on 16 August. Initially, there was just a large cloud minimum area that was caused by subsidence beneath a mid-level low. Based on the expected movement of upper-level divergence into this area, JTWC forecast the development of Tropical Depression 19W. When strong upper-level divergence did move into this area, convection began to rapidly develop. This cloudiness began to coil beneath the mid-level low, and estimates of 20- to 25-kt (10- to 13-m/sec) surface winds from satellite data prompted the issuance of a Tropical Cyclone Formation Alert at 160230Z. The first warning, at 170000Z, addressed further development of the tropical cyclone.

Tropical Depression 19W's unusual curved track to the north, west, and then south appears to coincide with the overall motion displayed by the larger, mid-level low. On 18 August, the mid-level low began to fill, weakening its influence on the tropical depression (Figure 3-19-1). The track of the cyclone straightened out, moving westward with the easterly steering flow. JTWC issued the final warning at 191200Z as the tropical depression approached the coast of China. No reports of damage were received.

Figure 3-19-1. A tight spiral of low cloudiness is associated with the exposed low-level circulation of Tropical Depression 19W (172346Z August NOAA visual imagery).



TROPICAL STORM ROGER
BEST TRACK TC-20W
22 AUG-28 AUG 89
MAX SFC WIND 50KT
MINIMUM SLP 983MB
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 28/00Z
F - 24/12Z
1st TCFA
2nd TCFA
E 115
120
125
130
135
140
145
150
155
160
165 E
N 50
45
40
35
30
25
N 20

TROPICAL STORM ROGER (20W)

Forming just north of Taiwan, Roger moved southeastward into the southern Ryukyu Islands, abruptly turned northeastward, and made landfall on Honshu. At the start, the forecast problem for this tropical cyclone was exacerbated by the difficulty in locating the system's complex center during its formative stages and the immediate threat it posed to DOD assets on Okinawa.

On 23 August, a tropical disturbance rapidly consolidated just north of Taiwan. Because of the developed cloud signature, JTWC opted to issue a Tropical Cyclone Formation Alert at 230500Z instead of reissuing the Significant Tropical Weather Advisory. When further development did not occur as rapidly as anticipated, the Alert was reissued the following day. Satellite data detected multiple vortices near the main convection mass and there was uncertainty about just where the system was going to consolidate. The fairly dense network of ship and land observations in the southern Ryukyu Islands began to show significant 12-hour pressure falls, and winds near the center of the disturbance increased to 25 kt (13 m/sec). In response, JTWC issued a 36-hour Tropical Depression Warning at 241200Z. Pressures continued to drop during the following 12 hours, and satellite and synoptic fixes appeared to converge. Finally, when it became apparent that one circulation center was going to emerge and intensify, JTWC issued a 72-hour Tropical Cyclone Warning at 250000Z.

On 25 August, in response to a short wave trough approaching from the north-northwest, the depression turned northeastward. The reason for the abrupt track change to the northeast was not immediately apparent because two vortices were involved. The low-level circulation center, in the southern portion of the cloud system, weakened, and another center in the northern portion strengthened. This switch in circulation centers initially made it appear as if Roger had executed a sharper turn and had accelerated faster than it actually did.

In addition to the major track change on 25 August, Roger also intensified to a tropical storm. Synoptic data revealed that gale force winds extended out from the circulation center more than 300 nm (555 km) into the [illegible] eastern semicircle. This large asymmetrical pattern of gales would accompany

Roger during the remainder of its lifetime. As the tropical cyclone (Figure 3-20-1) moved steadily northeastward, it gradually intensified. Roger reached a peak intensity of 50 kt (26 m/sec) early on 27 August, just prior to making landfall on Shikoku at Cape Muroto, which is located 100 nm (185 km) southwest of the city of Osaka.

At landfall, Roger's convection became more centralized and upper-level outflow remained good. In addition, the cyclone accelerated, increasing winds in the southeastern semicircle. As a consequence, Roger's track across central Honshu created considerable havoc. Two people drowned in swollen rivers and a third was killed in one of many landslides. Some areas in Roger's path recorded over 19 inches (485 mm) of rain. Widespread disruption of air traffic and railway service stranded over 37,000 travelers. Also, due to high winds, the new Seto Ohashi Bridge across the Inland Sea between Honshu and Shikoku was closed for the first time since it opened in April 1988.

At 271200Z, Tropical Storm Roger moved into the Sea of Japan and continued to accelerate under the influence of stronger westerly winds aloft. Even though the circulation center was over water, the combined effects of surface friction from the rugged topography of northern Honshu and increased westerly winds aloft weakened the tropical cyclone. At 280000Z, the final warning was issued as the extratropical remnants of Roger sped northeastward across Hokkaido.

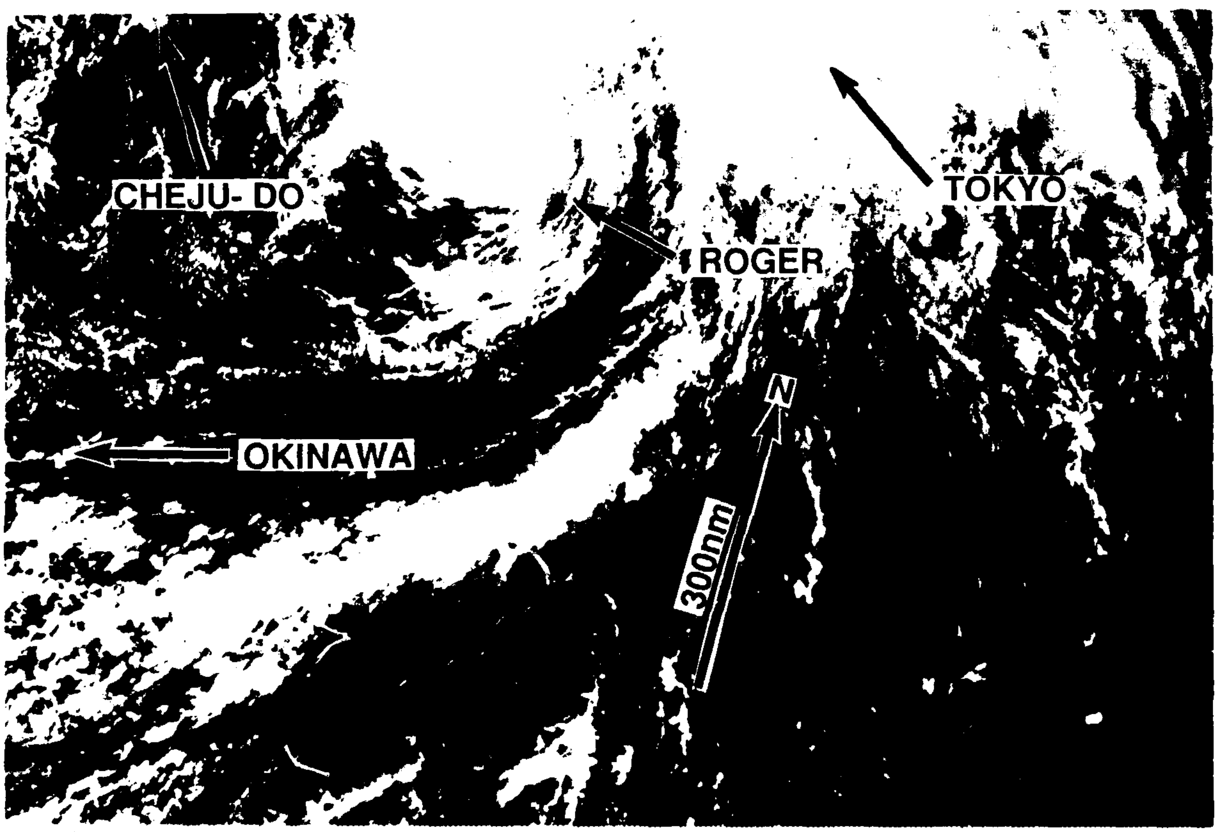


Figure 3-20-1. Near peak intensity, Roger approaches central Honshu (262343Z August DMSP visual imagery).

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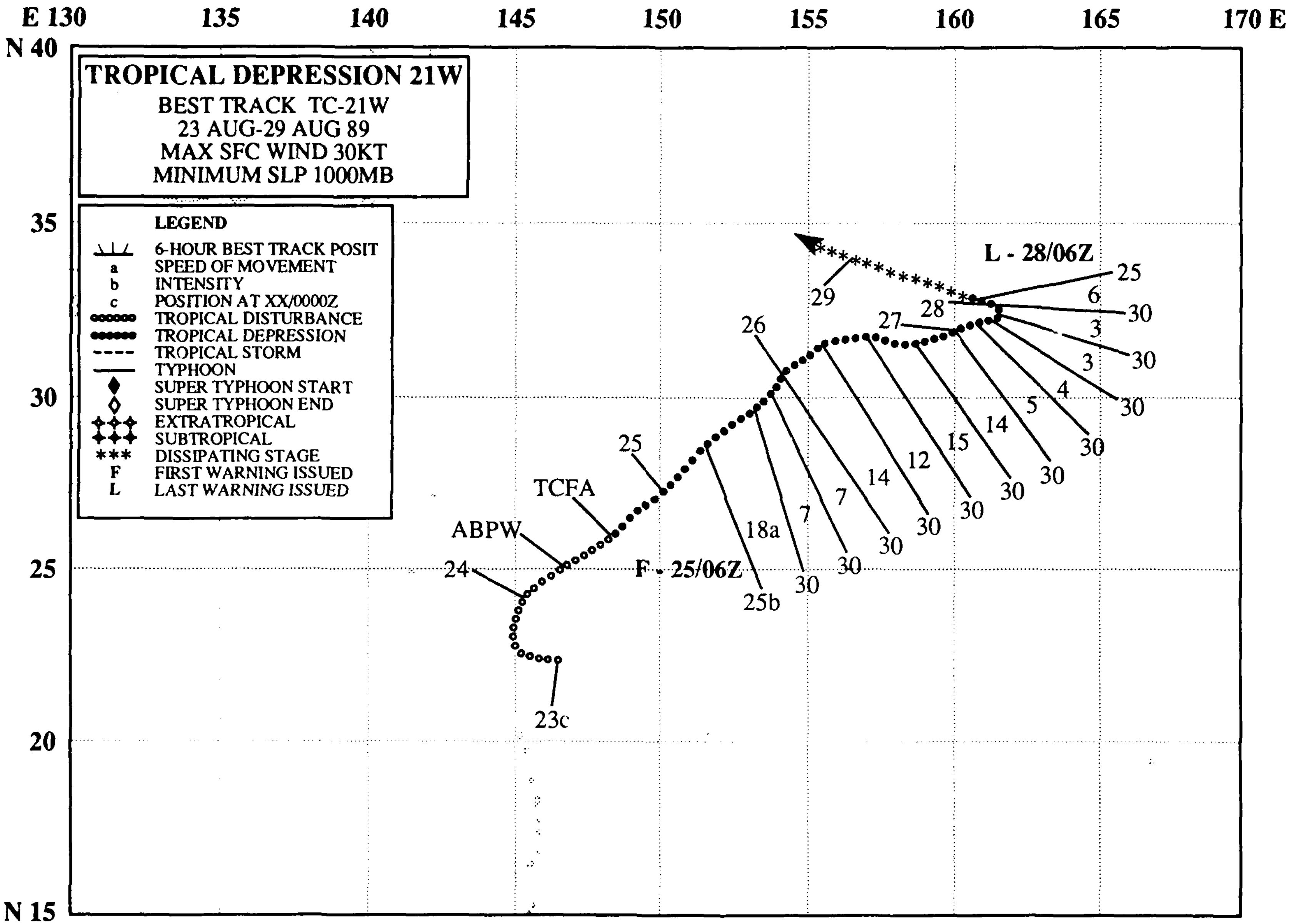
TROPICAL DEPRESSION 21W
BEST TRACK TC-21W
23 AUG-29 AUG 89
MAX SFC WIND 30KT
MINIMUM SLP 1000MB
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 130
135
140
145
150
155
160
165
170 E
N 40
35
30
25
20
N 15
L - 28/06Z
F - 25/06Z
TCFA
ABPW
23c
24
25
25b
18a
26
27
28
29

TROPICAL DEPRESSION 21W

The eighth and final tropical cyclone of August, Tropical Depression 21W developed northeast of the Mariana Islands. Because JTWC recognized that intensification would be inhibited by strong vertical wind shear, only Tropical Depression Warnings were issued.

As Tropical Storm Roger (20W) passed through the southern Ryukyu Islands on 23 August, a disturbance formed on the eastern end of the monsoon trough which extended eastward across the northern-most Mariana Islands. The 24 August Significant Tropical Weather Advisory mentioned the disturbance and its poor potential for development. During the night, the disturbance became better organized and its potential for development was upgraded to fair. A Tropical Cyclone Formation Alert was issued at 241200Z, after the disturbance continued to develop during the normal diurnal convective minimum. Further development (Figure 3-21-1) led to the first

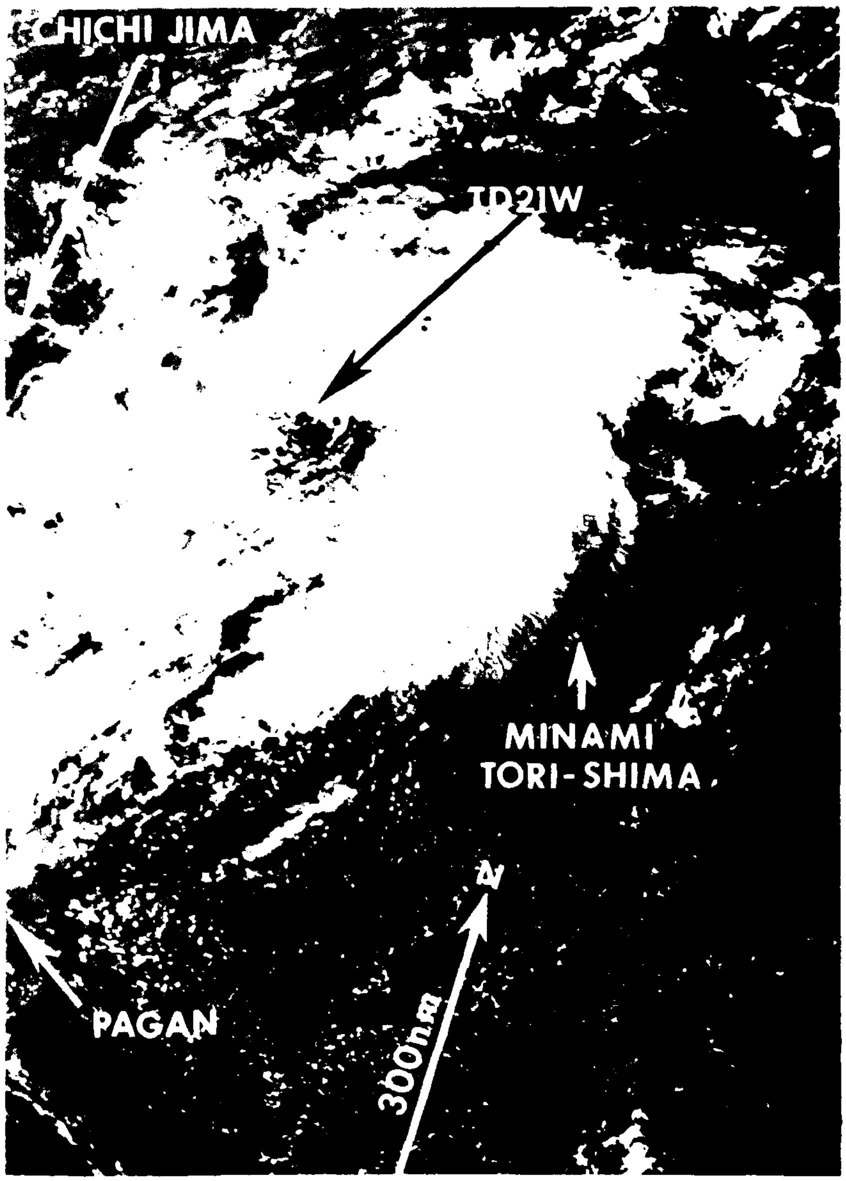

Figure 3-21-1. Convective organization continues to increase after the Alert was issued (242242Z August DMSP visual imagery).

warning at 250600Z. A Tropical Depression Warning was issued rather than a tropical cyclone warning since the low-level circulation was displaced to the west of the deep convection and the system was not expected to be long-lived because of strong westerly wind shear aloft.

While the upper-level winds restricted the tropical cyclone's outflow, the deep southwesterly monsoonal flow carried the low-level circulation center on an unusually long track to the northeast. Late on 25 August, Tropical Depression 21W slowed abruptly as it moved into an area of weaker vertical shear. Coincidentally, the low-level circulation center moved beneath the central cloud mass, and the intensity increased to 30 kt (15 m/sec).

On 26 August, the depression accelerated in response to a surge in the southwest monsoon. Shortly thereafter it started interacting with a shear zone that trailed from a weak cold front. Tropical Depression 21W appeared to be on the verge of transitioning to an extratropical system; however, on 27 August, mid-level steering weakened, the system stalled, and central convection reappeared.

Within a day, unfavorable conditions returned aloft, as northwesterlies moved over the system and began once more to strip away the central convection. As a consequence, the amount of convection decreased and the low-level circulation center became exposed. A weakening Tropical Depression 21W suddenly started tracking northwestward. At 280600Z, with the low-level circulation center separated more than one degree to the west of the convection, the final warning was issued. JTWC did not receive any reports of damage caused by the tropical cyclone.

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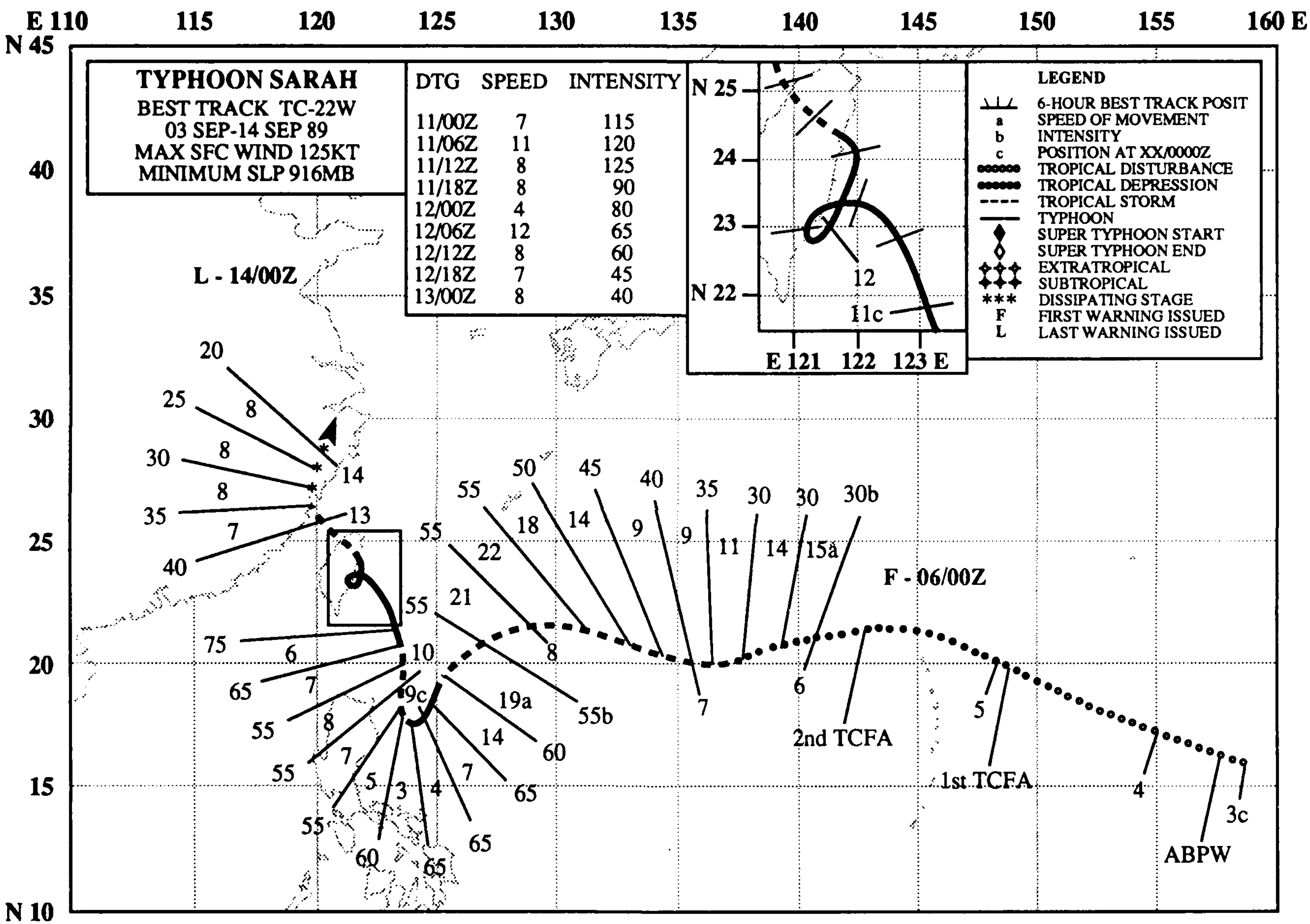
TYPHOON SARAH
BEST TRACK TC-22W
03 SEP-14 SEP 89
MAX SFC WIND 125KT
MINIMUM SLP 916MB
DTG SPEED INTENSITY
11/00Z 7 115
11/06Z 11 120
11/12Z 8 125
11/18Z 8 90
12/00Z 4 80
12/06Z 12 65
12/12Z 8 60
12/18Z 7 45
13/00Z 8 40
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 14/00Z
F - 06/00Z
2nd TCFA
1st TCFA
ABPW
E 110 115 120 125 130 135 140 145 150 155 160 E
N 45 40 35 30 25 20 15 N 10
N 25 24 23 N 22
E 121 122 123 E

TYPHOON SARAH (22W)

The first of the September tropical cyclones, Sarah proved to be a bona fide challenge to forecasters. The cyclone apparently underwent a binary interaction with a secondary low east of Luzon and later, when it stalled, was involved with the development of a sympathetic low* on the lee side of Luzon. From genesis involving two distinct cloud masses to accelerating toward the Philippines, stalling just east of Luzon, moving north and rapidly reintensifying, then looping over eastern Taiwan, Sarah was one of the most difficult storms of the year to forecast.

The first day of September, the monsoon trough stretched across the western Pacific in a southwest to northeast orientation between 10° to 20° north latitude, and supported several discrete convective cloud masses. Near Minami Tori-shima, a distinct TUTT cell was evident in satellite imagery. About 600 nm (1110 km) to the southeast, a disturbed area of weather persisted in the monsoon trough. There was little convection associated with the TUTT cell, however, the convection associated with the disturbance was listed on the Significant Tropical Weather Advisory. Two Tropical Cyclone Formation Alerts were issued before the first warning. Complex interactions between the TUTT cell, the disturbance and a second disturbance resulted in conditions favorable for development, and the first warning on Tropical Depression 22W was issued at 060000Z.

The Depression tracked as forecast to the west and was upgraded to Tropical Storm Sarah on the 061800Z warning. By midday on 7 September, Sarah started to accelerate to the northwest towards Okinawa and the tropical storm was relocated on the 071800Z to reflect the acceleration.

Forecasters at JTWC expected the north-westward motion to be short-lived and predicted a turn back to the west. However, on 8 September, the tropical storm turned west-southwest, then south-southwest, and nearly stalled east of Luzon on 9 September. Binary interaction with a secondary low appeared to be

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* The formation of a sympathetic low is documented in relation to systems approaching Taiwan (Brand and Blelloch, 1973), but not for systems off the Philippine Islands

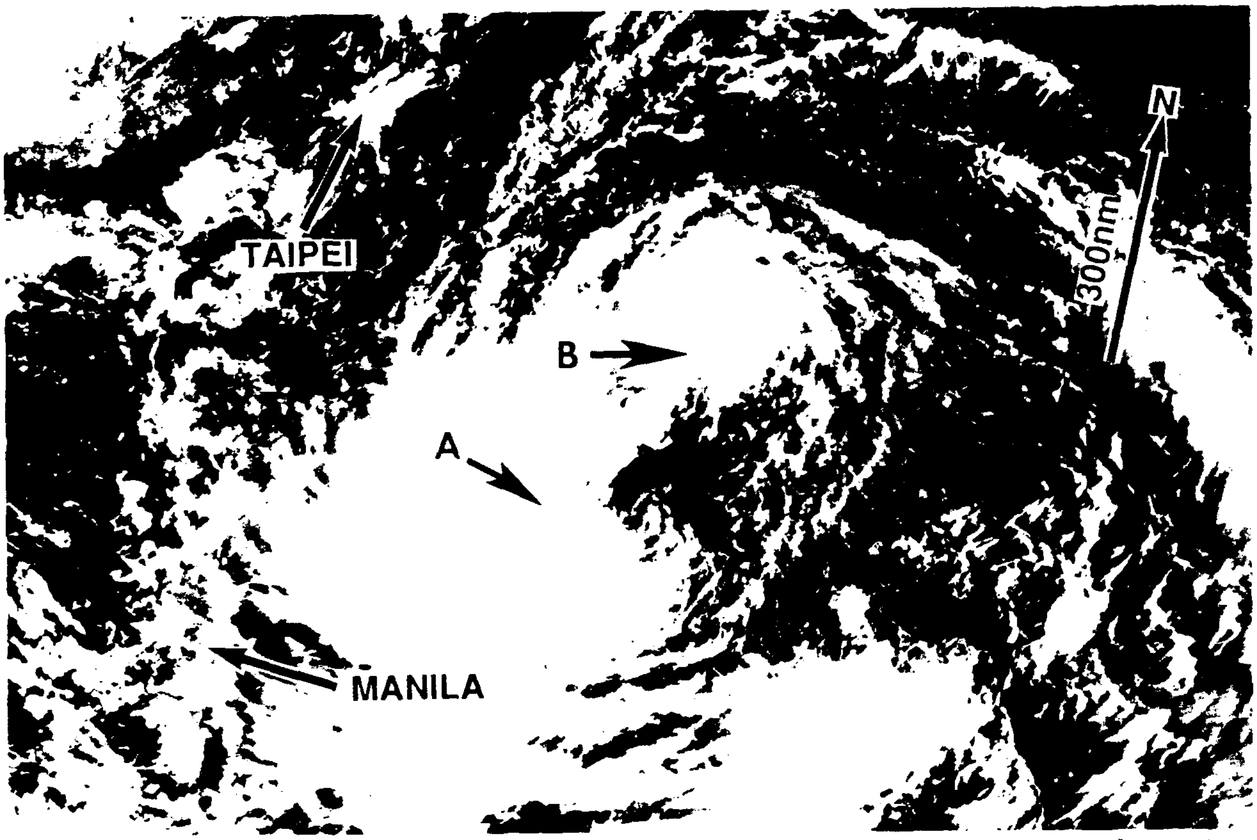
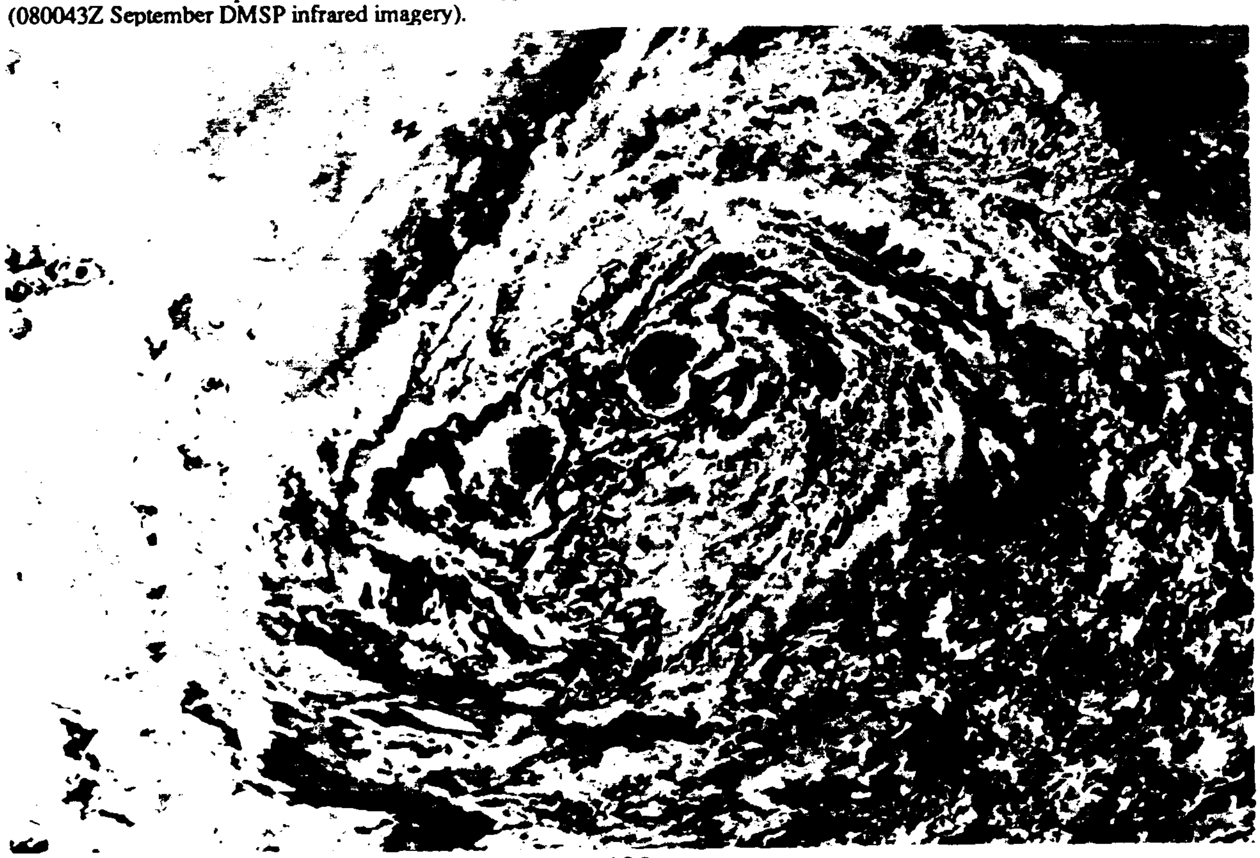


Figure 3-22-1. Matched pair of visual (above) and enhanced infrared (below) images showing two centers of convection. Point A is the mass of persistent convection that appears to have undergone binary interaction with Sarah which is at point B (080043Z September DMSP infrared imagery).



the cause for Sarah's unusual movement. While there was a persistent convective mass (Figure 3-22-1) on the satellite images, there was no firm evidence of this secondary low at the surface on 8 September.

Upgraded to typhoon intensity at 081800Z, Sarah drifted south slowly and then abruptly headed north. During this time, a sympathetic lee-side low (Figure 3-22-2) formed along the northwest side of Luzon. As Sarah moved north, the cloud mass associated with this lee-side low crossed Basco Island north of Luzon and tracked rapidly around the east side of Sarah and to the northeast. Since Basco Island (WMO 98135) reports did not indicate a wind shift as the convective mass passed by, no Alert on this secondary convective area was issued. Sarah's prolonged stay just east of Luzon, coupled with the enhanced southwesterly monsoon flow being drawn over the Philippine Islands resulted in at least 31 fatalities, and extensive property and crop damage on Luzon. In addition, rare tornadoes touched down on 10 September. One caused approximately $150,000 of damage to the San Miguel Naval Communications Station located 38 nm (70 km) northwest of Manila. No other U. S. military installations reported major damage. Camp John Hay located near Baguio reported the strongest winds observed at a U.S. military installation of 42 - 48 kt (22-25 m/sec) during the period from 091500Z to 110430Z.

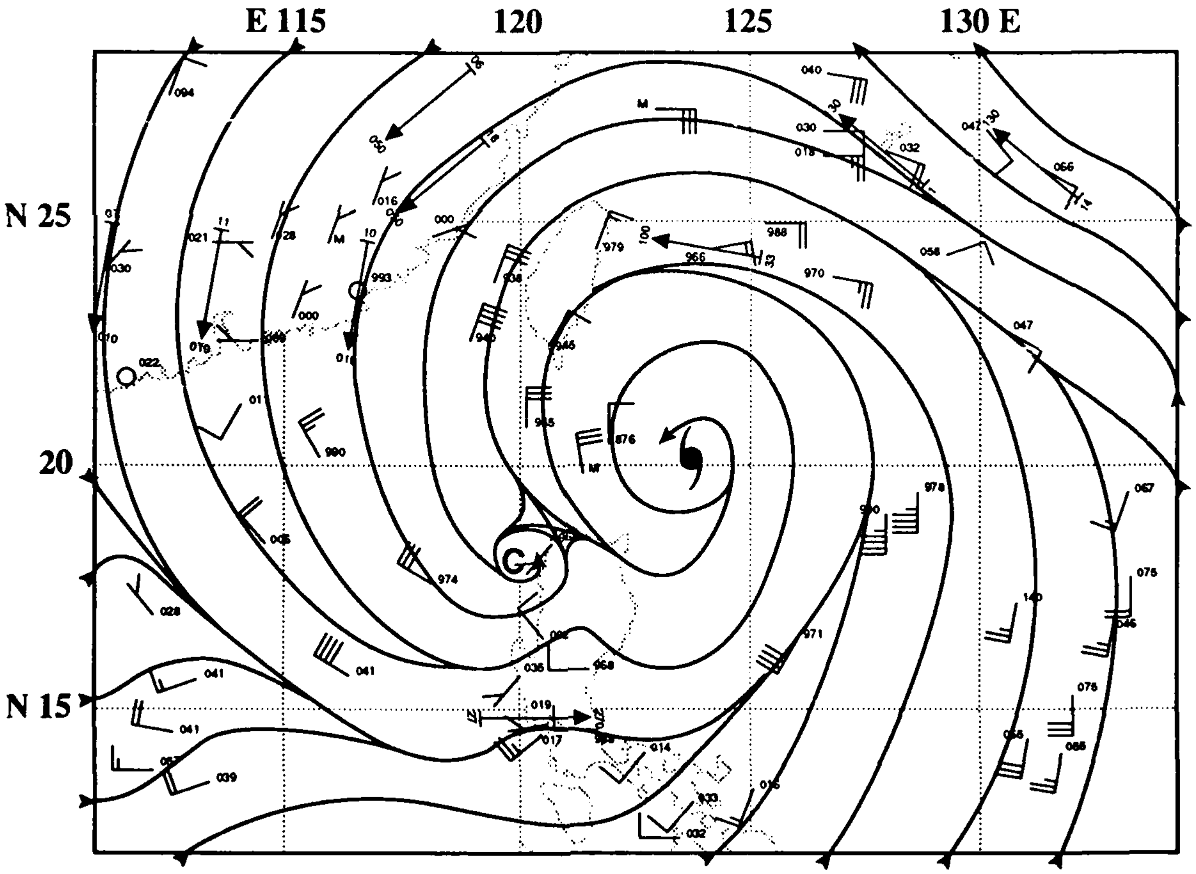


Figure 3-22-2. 101220Z surface/gradient wind analyses shows the sympathetic low along the northwest coast of Luzon.

Moving north into an area of efficient multiple outflow channels, Sarah (Figures 3-22-3 and 3-22-4) explosively deepened. The typhoon peaked at 125 kt (64 m/sec) before interaction with the rugged mountains of Taiwan caused it to weaken. On 10 September, the typhoon was forecast to track north, passing approximately 60 nm (110 km) east of Taiwan on 11 September. It was expected to merge with an approaching mid-latitude front and recurve to the northeast into Kyushu, Japan. Although this was the overall track taken by the secondary cloud maximum that had formed on the lee-side of Luzon and looped around the east side of Sarah as both systems moved north, Sarah did not follow suit. Sarah moved onshore Taiwan with maximum winds near 90 kt (46 m/sec). It then tracked south a short distance along the eastern edge of the mountain range and finally completed a counterclockwise loop off the coast. Approximately 12 hours later, Sarah reentered the coast farther north, weakened and was downgraded to a tropical storm Sarah at 121200Z as it crossed the rugged mountains of Taiwan. The cyclone did not regain its organization as it crossed the Taiwan

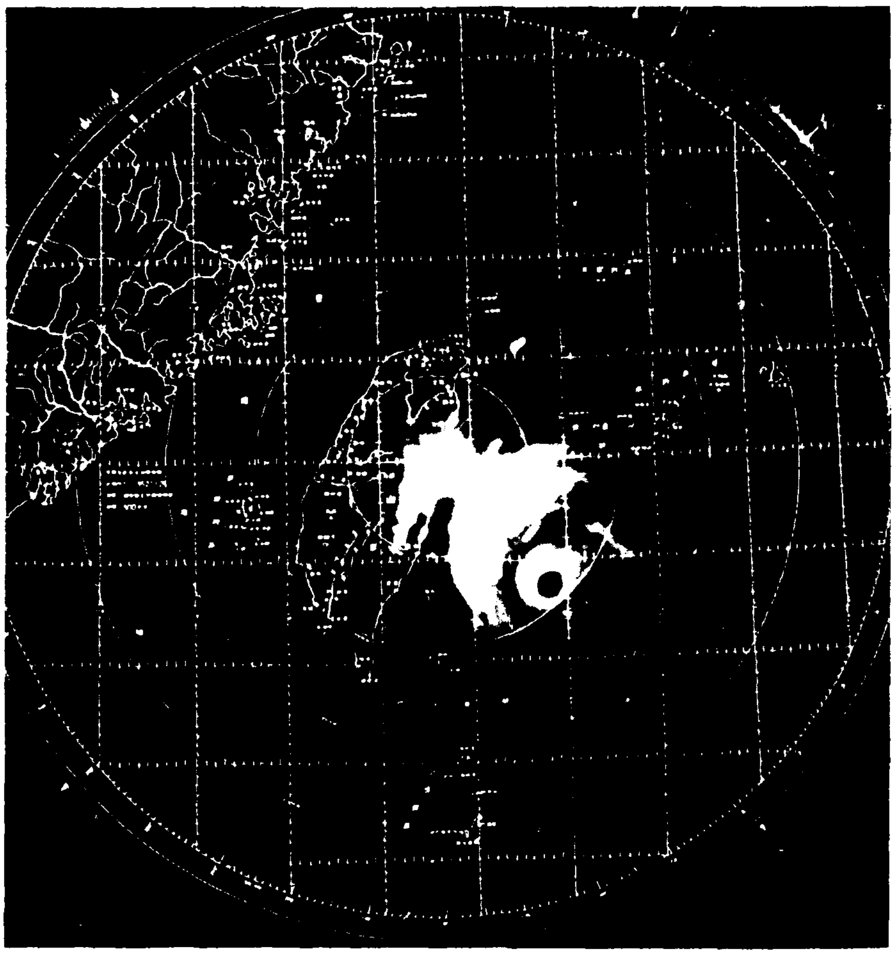


Figure 3-22-3. Radar display of Sarah from Hualien (WMO 46699) at 110500Z. Comparison with Figure 3-22-4, which is close in time, shows the contrast between the remotely sensed precipitation echoes from radar and the cloud top topography as viewed from space (photograph courtesy of the Central Weather Bureau, Taipei, Taiwan).

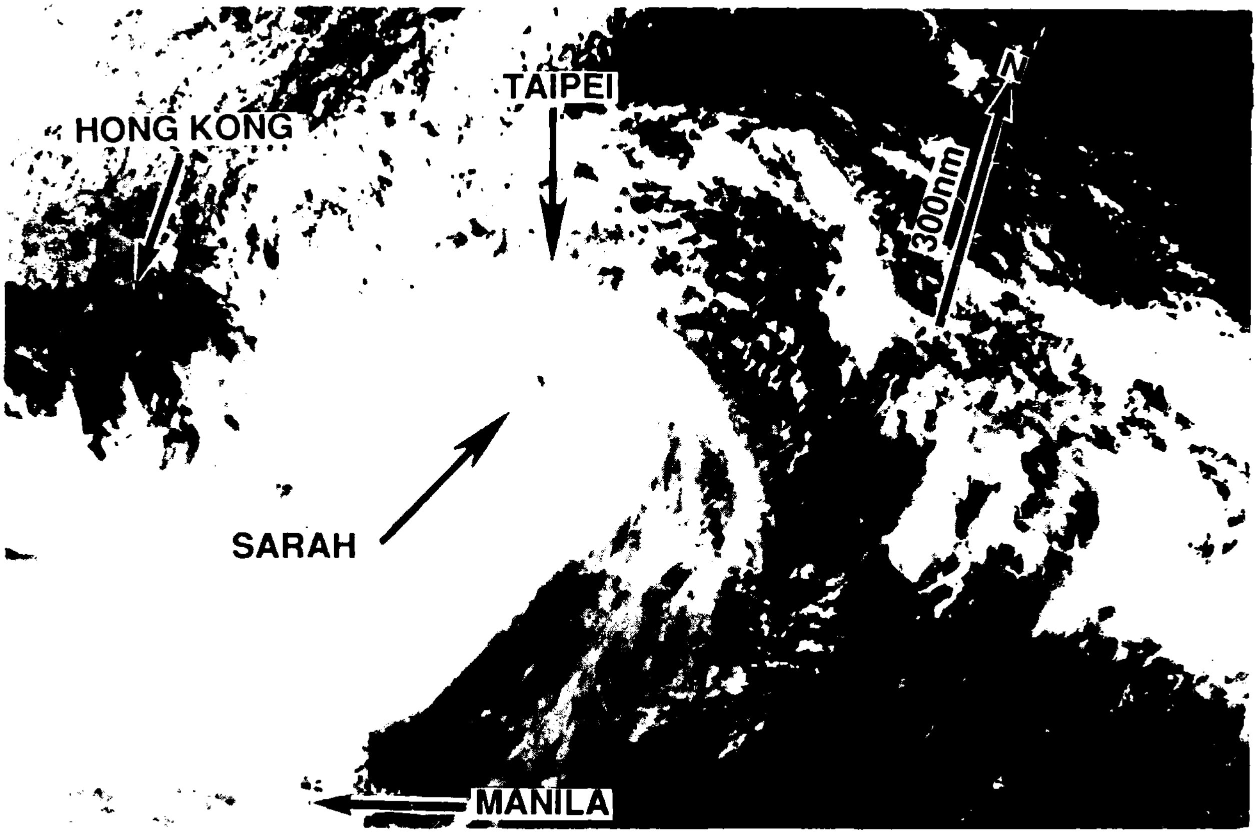


Figure 3-22-4. Matched visual (above) and enhanced infrared (below) pair of images showing Sarah near peak intensity (100517Z September DMSP visual and infrared imagery).

Straits and was downgraded to a tropical depression after it entered the eastern coast of China at 130600Z (Figure 3-22-5). The last warning was issued at 140000Z as the system dissipated over eastern China. Press reports indicated that 13 people died on Taiwan, and that the 12000-ton freighter **Lung Hao** (Figure 3-22-6) broke in half off Hualien, Taiwan. No reports of damage were received from China.

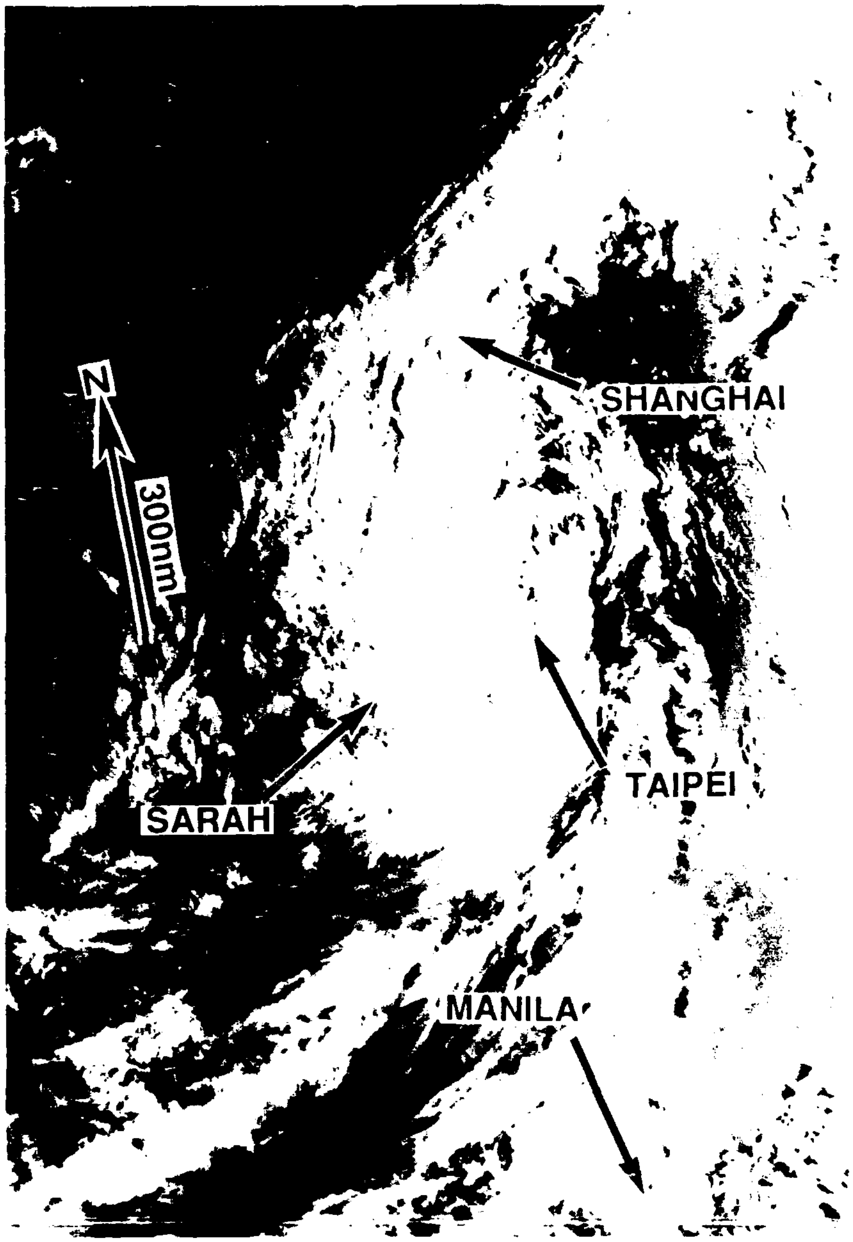


Figure 3-22-5. Sarah weakens over the coast of China (130006Z NOAA visual imagery).

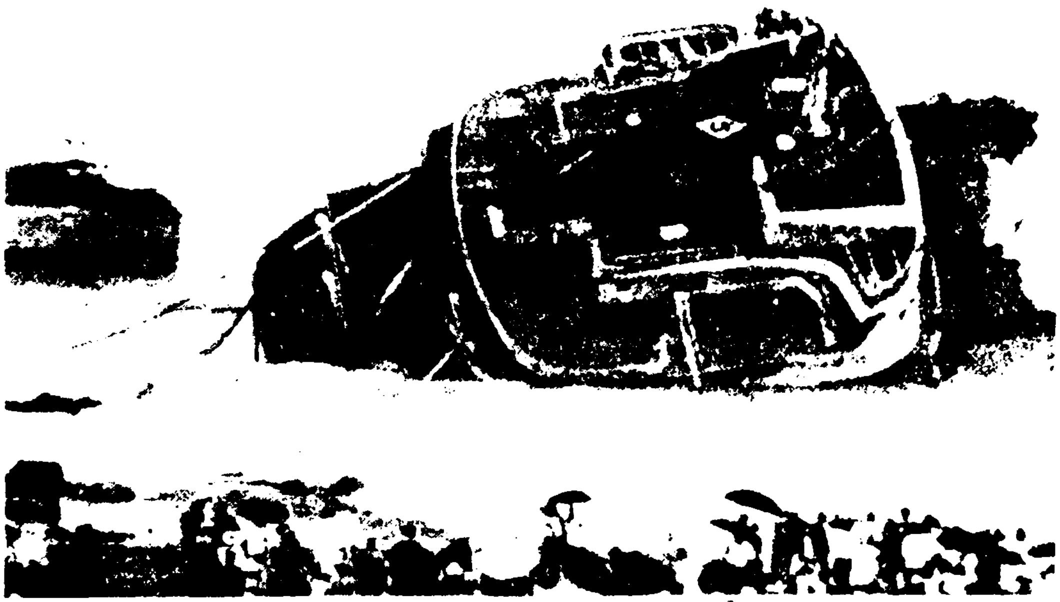
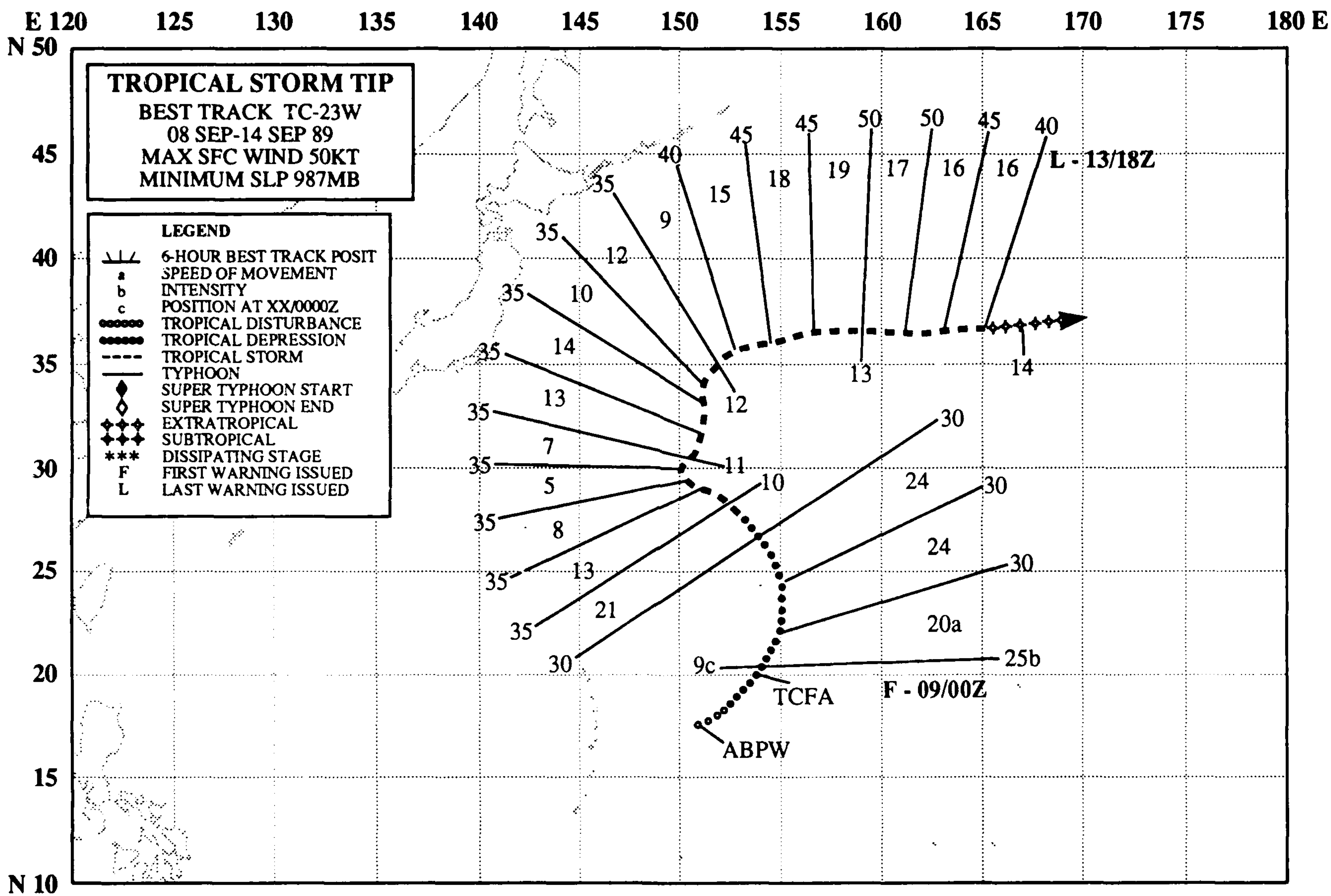


Figure 3-22-6. The wreck of the freighter **Lung Hao**, which was broken in half on the coast of Taiwan by Typhoon Sarah (photo courtesy *Pacific Daily News*, Agana, Guam).



TROPICAL STORM TIP
BEST TRACK TC-23W
08 SEP-14 SEP 89
MAX SFC WIND 50KT
MINIMUM SLP 987MB
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 120
125
130
135
140
145
150
155
160
165
170
175
180 E
N 50
45
40
35
30
25
20
15
N 10
L - 13/18Z
F - 09/00Z
TCFA
ABPW
9c
25b
20a

TROPICAL STORM TIP (23W)

Generating in early September at the eastern end of the monsoon trough, Tip executed an unusual track to the northeast, then recurved after moving northwestward around the subtropical ridge, and finally tracked eastward with the polar westerlies. Tip reached its peak intensity at 37° north latitude two days after recurvature.

Tip developed east of the Mariana Islands in an area of enhanced convection at the eastern-most extension of the southwest monsoon. At 080600Z, JTWC mentioned the area on the Significant Tropical Weather Advisory as having fair potential for further development. Increases in the amount, depth, and organization of the convection caused JTWC to issue a Tropical Cyclone Formation Alert at 082300Z. With synoptic data supporting a closed low-level circulation and indicating 25 kt (13 m/s) sustained surface winds, JTWC issued the first warning on Tropical Depression 23W.

During the time that the depression moved rapidly northeastward, and then northwestward, the "spin-up" of the system was slow, partially due to the large size of the vortex. By the time Tip reached the axis of the subtropical ridge and slowed late on 10 September, the bulk of the supporting convection from the monsoonal flow had moved away to the east and north, and had dissipated, leaving only a small ragged patch of dense overcast near the partially exposed low-level circulation center.

At 110600Z, Tip (Figure 3-23-1) began

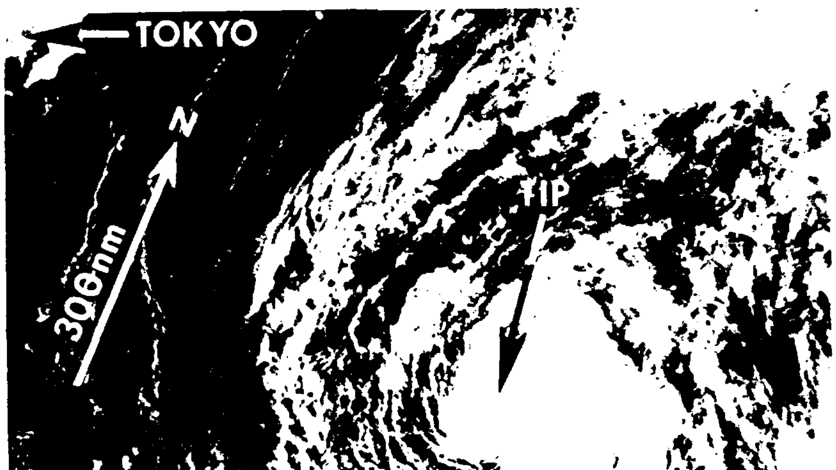


Figure 3-23-1. Tip accelerates to the northeast and begins recurving 400 nm (640 km) north-northeast of Minami Tori-shima (110324Z September NOAA visual imagery).

to accelerate to the north-northeast. During the next 18 hours, Tip appeared to be undergoing extratropical transition, but, at 120000Z, the tropical cyclone regained enough of its central convection to maintain its warm core. This additional translational effect from the acceleration assisted Tip in reaching its peak intensity of 50 kt (26 m/sec) at 130000Z.

During the early morning hours of the 13 September, Tip's convection tracked south-southeastward with the upper-level flow. Daylight satellite imagery revealed that the low-level circulation was well to the north of the convection. At 131800Z, JTWC issued the final warning on Tropical Storm Tip and passed warning responsibility for the extratropical gales to the Naval Weste-n Oceanography Center at Pearl Harbor, Hawaii.

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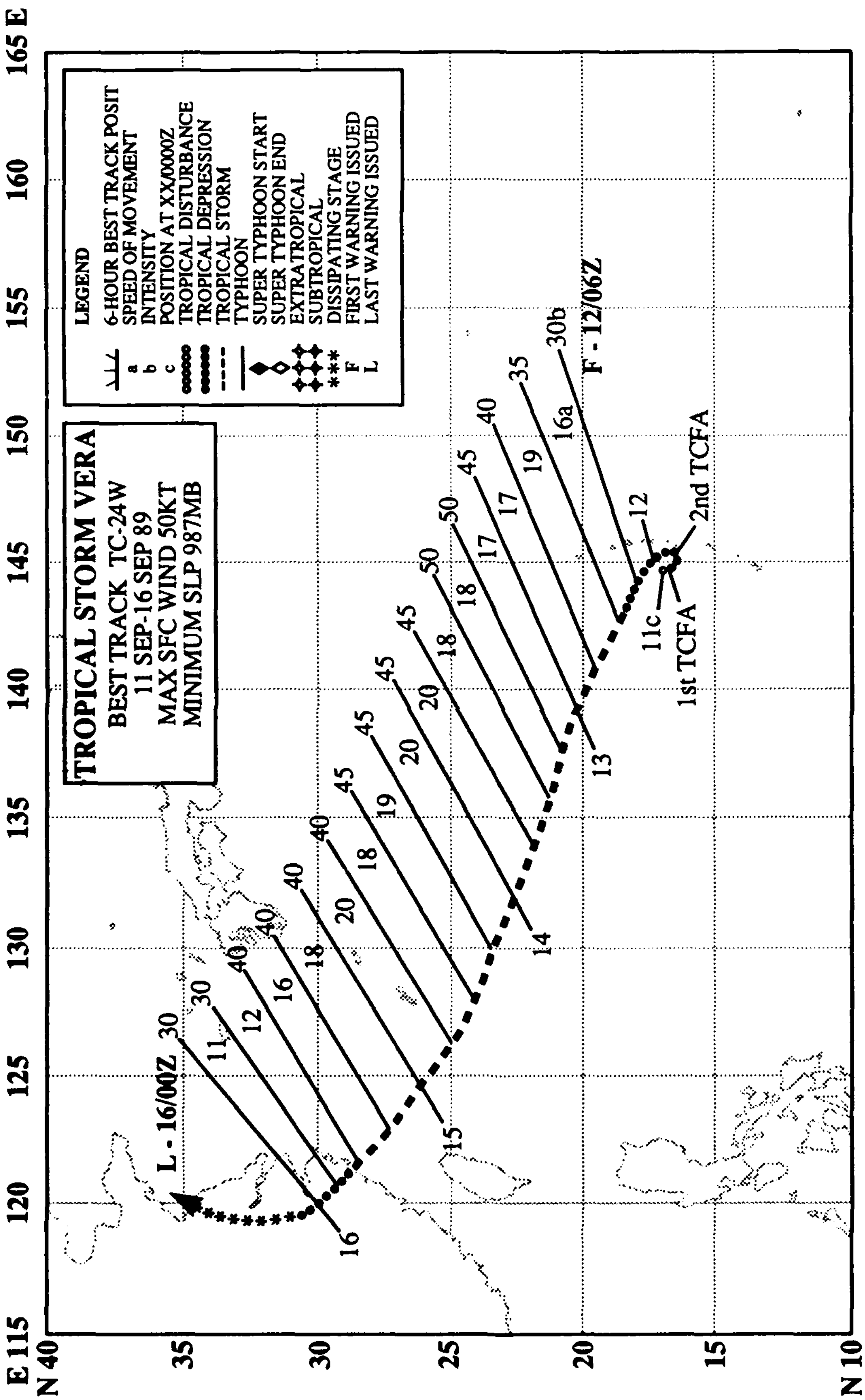
TROPICAL STORM VERA
BEST TRACK TC-24W
11 SEP-16 SEP 89
MAX SFC WIND 50KT
MINIMUM SLP 987MB
LEGEND
6-HOUR BEST TRACK POSIT
SPEED OF MOVEMENT
INTENSITY
POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
F - 12/06Z
L - 16/00Z
1st TCFA
2nd TCFA
E 115
120
125
130
135
140
145
150
155
160
165 E
N 40
35
30
25
20
15
N 10

TROPICAL STORM VERA (24W)

The third tropical cyclone in September, Vera generated north of Guam. After some initial erratic motion, the cyclone moved on a west-northwestward track, threatened Okinawa, and made a devastating landfall just south of Shanghai.

Vera generated in an area of low-level convergent flow in the monsoon trough approximately 250 nm (465 km) north of Guam. Persistent convection had not been observed with this system prior to 101200Z. By then, however, the combination of persistent convection, a preexisting low-level circulation center, and sea-level pressures below 1004 mb triggered JTWC to issue the first Tropical Cyclone Formation Alert at 110430Z. Both satellite imagery and synoptic data indicated efficient outflow over the low-level circulation center suggesting good potential for further development. JTWC reissued the Alert at 111500Z as the disturbance moved to the southeast, and out of the original Alert box.

After the initial erratic motion, the convection organized around the circulation center, and the cyclone settled into a track to the west-northwest. JTWC issued the first warning on Tropical Depression 24W at 120600Z. Moving into increased steering flow along the southern side of the subtropical ridge, the tropical cyclone increased its translational speed and continued to intensify. At 121200Z, JTWC upgraded the depression to Tropical Storm Vera.

Due to two impinging TUTT cells, which constricted the efficiency of its upper-level outflow, one to the northwest and one to the northeast, Vera (Figure 3-24-1) intensified

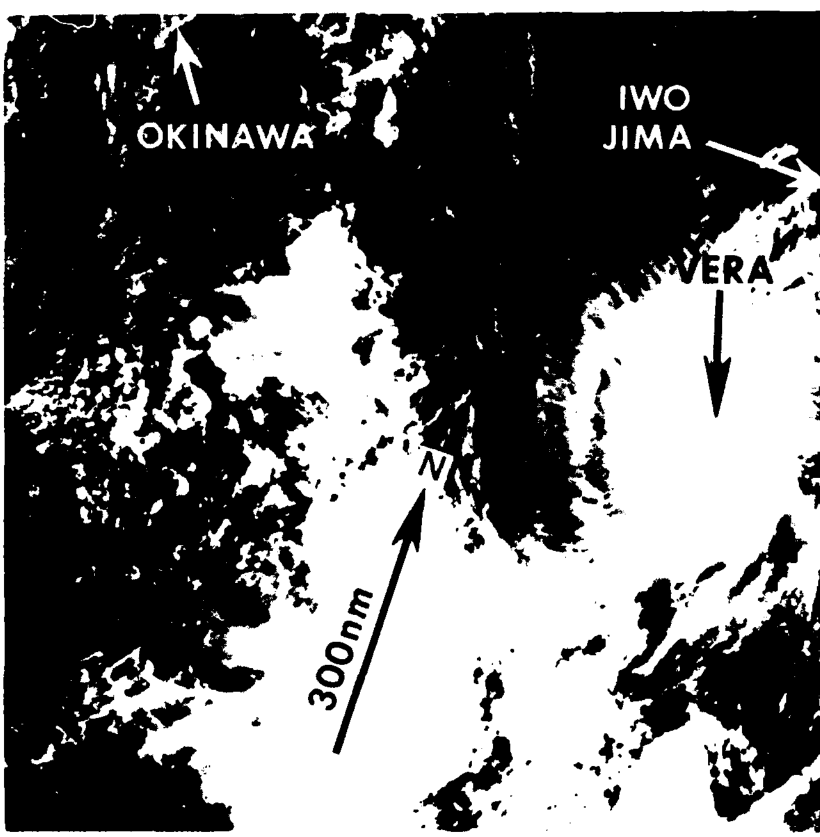

Figure 3-24-1. Convection flares shortly before Vera reaches it peak intensity (130042Z September DMSP visual imagery).

slowly, reaching only a peak intensity of 50 kt (26 m/sec) at 130600Z. On 14 and 15 September, as the tropical cyclone accelerated to a forward speed of 20 kt (10 m/sec), it started to weakened due to strong vertical wind shear. Vera passed 100 nm (185 km) southwest of Okinawa and maintained tropical storm intensity until after it made landfall approximately 150 nm (240 km) south of Shanghai. At 151800Z, the cyclone was downgraded to a tropical depression. JTWC issued the final warning at 160000Z, and the system dissipated over land 18 hours later. No damage reports were noted from Okinawa, however, press releases from China cited Vera as the most powerful cyclone to hit the low-lying Zhejiang province in southeastern China in decades. Estimates ran as high as 500 fatalities, 700 injured and hundreds missing. Heavy rains reportedly caused extensive flooding and crop damage.

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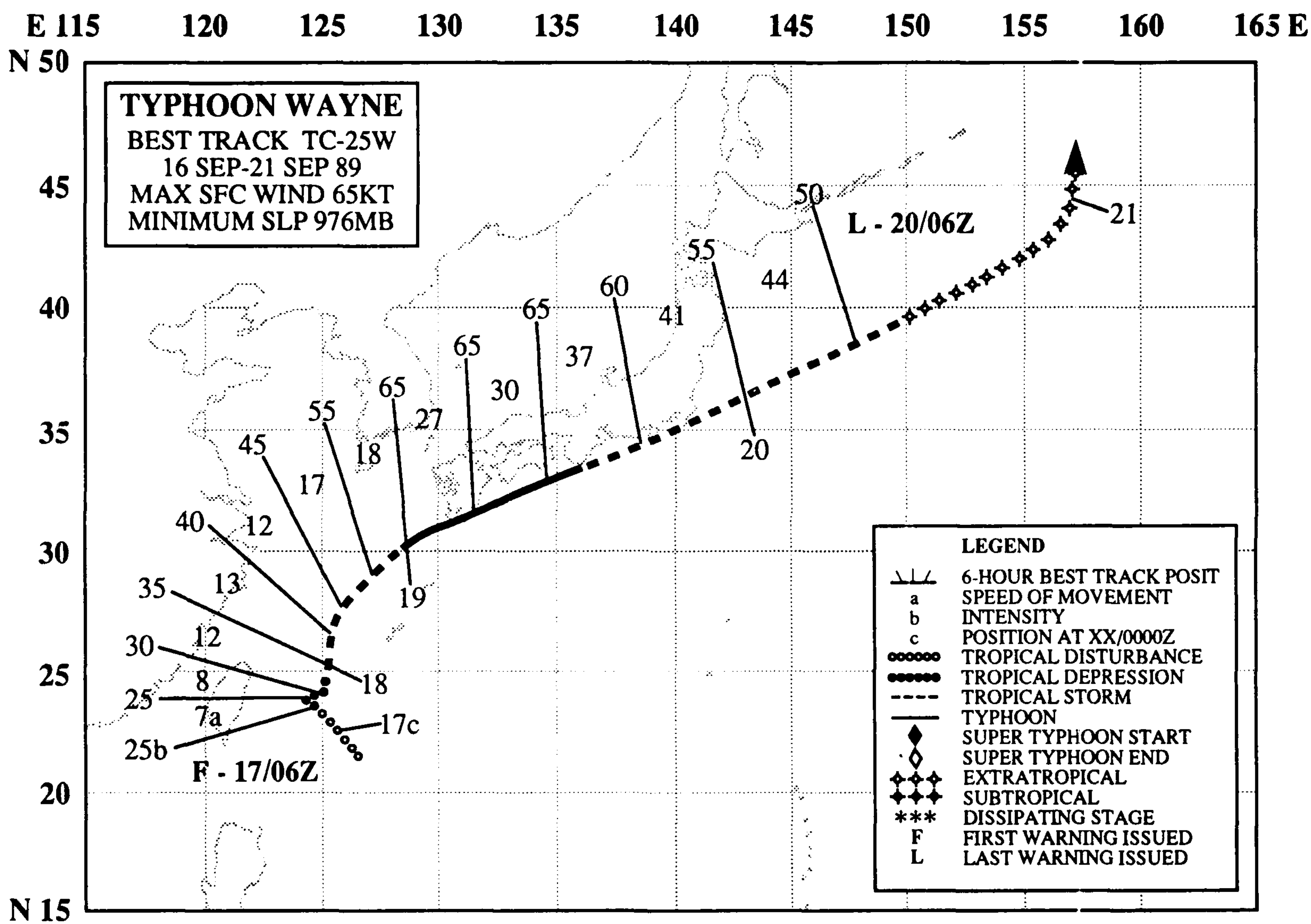
TYPHOON WAYNE
BEST TRACK TC-25W
16 SEP-21 SEP 89
MAX SFC WIND 65KT
MINIMUM SLP 976MB
E 115
120
125
130
135
140
145
150
155
160
165 E
N 50
45
40
35
30
25
20
N 15
L - 20/06Z
F - 17/06Z
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TYPHOON WAYNE (25W)

The last of four tropical cyclones to develop in September, Wayne was also the last tropical cyclone of 1989 to affect Japan. It was unique in that it intensified after recurvature. Wayne caused considerable destruction, mudslides and some deaths in Japan.

About 24 hours after Tropical Storm Vera (24W) had dissipated over eastern China, the first warning on Tropical Depression 25W was issued at 170600Z indicating maximum sustained winds of 25 kt (13 m/sec). The depression formed approximately 300 nm (555 km) southwest of Okinawa and was expected to continue on a northwestward track into China before it could reach tropical storm intensity. JTWC issued a second Tropical Depression Warning at 171800Z. At that time, the six-hour movement was thought to have been to the west; however, detailed post-analysis indicated that the system had, in fact, turned northward. The turn to the north as well as further intensification became evident by 180000Z. The depression was upgraded to Tropical Storm Wayne and was forecast to track northeast through central Honshu and dissipate near Tokyo.

JTWC forecasters maintained that forecast scenario until 181200Z, when they took the track more northward into the Sea of Japan. This change in thinking was based on the persistent northward movement and the NOGAPS prognostic series that indicated a deepening low in the Sea of Japan would attract the system. JTWC's prognostic reasoning

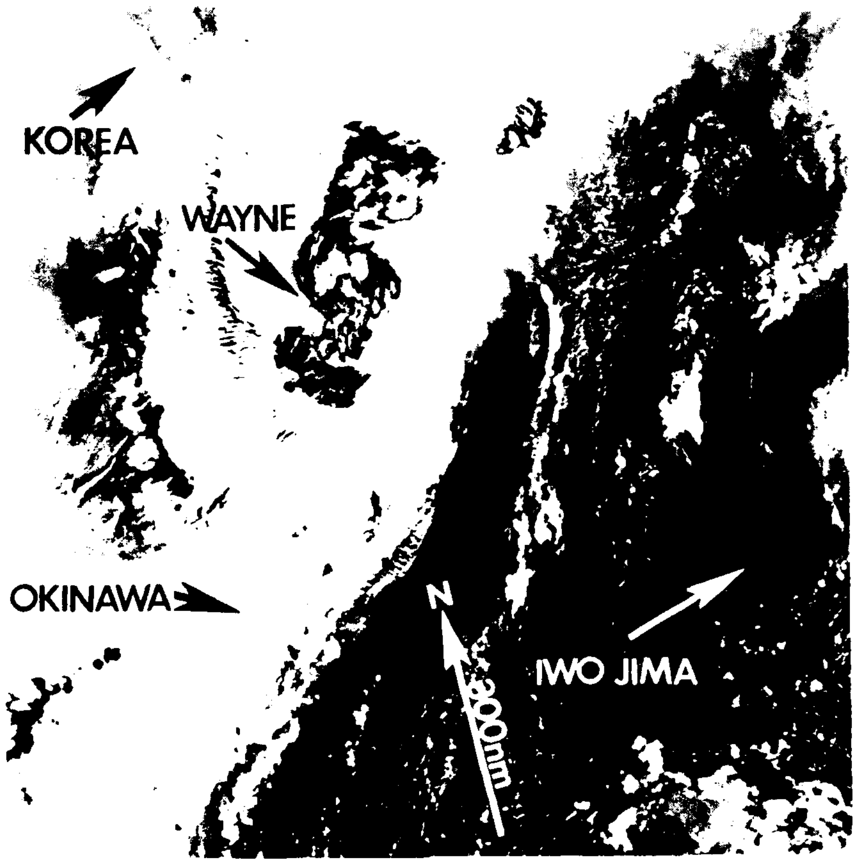

Figure 3-25-1. Typhoon Wayne along the southern coast of Japan (190932Z September DMSP enhanced infrared imagery).

discussed the possibility of the system being caught by the approaching frontal system and remaining south of Japan. The strong vertical wind shear present east of Korea was expected to prevent Wayne from exceeding tropical storm intensity.

Surprisingly, satellite imagery at 181800Z indicated Wayne had apparently developed an eye. The warning was amended four hours later as subsequent satellite imagery confirmed the presence of an eye and further intensification. At 190000Z, Wayne was upgraded to a typhoon. While not a common occurrence, intensification after recurvature can occur when a tropical cyclone recurves at relatively low latitudes; and the jet stream provides an efficient outflow channel. A favored time for such intensification (Guard, 1983) is during the fall when warm sea surface temperatures extend into higher latitudes.

Significant acceleration started at 190000Z, and Wayne (Figure 3-25-1) was downgraded to a tropical storm at 191800Z. Fortunately for Japan, as Wayne accelerated, the translational speed diminished the maximum sustained wind speeds in the northwest quadrant, which was over land. Yokota AB, Japan (WMO 47642), experienced maximum sustained winds of 14 kt (7 m/sec) with a peak gust to 19 knots (10 m/sec), even though Wayne passed only 45 nm (85 km) to the southeast. Tateyama (WMO 47672), southeast of Yokosuka at the mouth of Sagami Bay, took a direct hit from Tropical Storm Wayne, and after the storm passed, the station recorded 60 kt (31 m/sec) sustained winds with gusts to 84 kt (43 m/sec). Heavy rains caused flooding and mudslides. News reports indicated at least seven people died and over 4000 homes were flooded.

By 191800Z, Wayne's translational speed had increased to 40 kt (74 km/hr) and the system began to transition into an extratropical low. JTWC issued the final warning on Wayne at 200600Z as it underwent a compound transition (Brand and Guard, 1978) and merged with a cold-core low east of Hokkaido.

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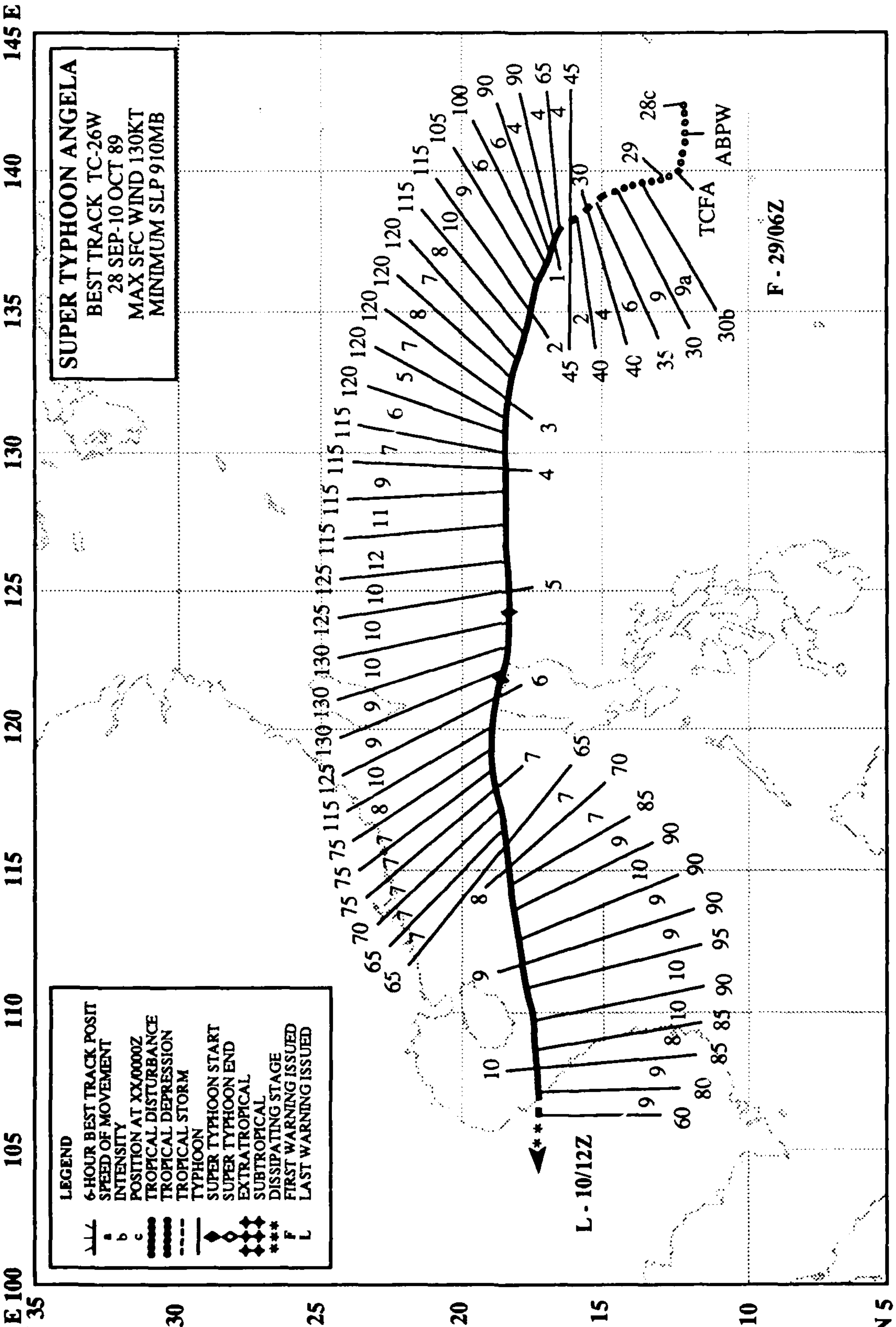

SUPER TYPHOON ANGELA
BEST TRACK TC-26W
28 SEP-10 OCT 89
MAX SFC WIND 130KT
MINIMUM SLP 910MB
LEGEND
6-HOUR BEST TRACK POSIT
SPEED OF MOVEMENT
INTENSITY
POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
F - 29/06Z
L - 10/12Z
TCFA
ABPW
E 100
105
110
115
120
125
130
135
140
145 E
N 35
30
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20
15
10
N 5

SUPER TYPHOON ANGELA (26W)

Angela was the first of three tropical cyclones to form in the monsoon trough during the three-day period 29 September to 2 October. It had the unique distinction of being in warning status longer than any other tropical cyclone in the western North Pacific this year — 12 days. From 29 September to 10 October, JTWC issued a total of 46 warnings on Angela. Angela also was one of five tropical cyclones to reach super typhoon intensity in 1989. Developing south of Guam, Angela tracked slowly westward and struck northern Luzon with super typhoon intensity causing a large number of casualties and wide spread destruction. It then continued into the South China Sea, where it reintensified, finally making landfall in central Vietnam.

During late September, the monsoon trough, located near 10° north latitude, became very active after a week of little convective activity. On 26 September an area of convection developed in the western Caroline Islands. The disturbed weather persisted for two more days, and was added as a suspect area to the 280600Z Significant Tropical Weather Advisory. As the disturbance moved to the southeast side of a Tropical Upper Tropospheric Trough (TUTT) cyclone, it organized rapidly. This resulted in the issuance of a Tropical Cyclone Formation Alert at 281730Z. The enhanced upper-level outflow from the TUTT low aided further development, and the first warning on Tropical Depression 34W (Figure 3-26-1) was issued at 290600Z.

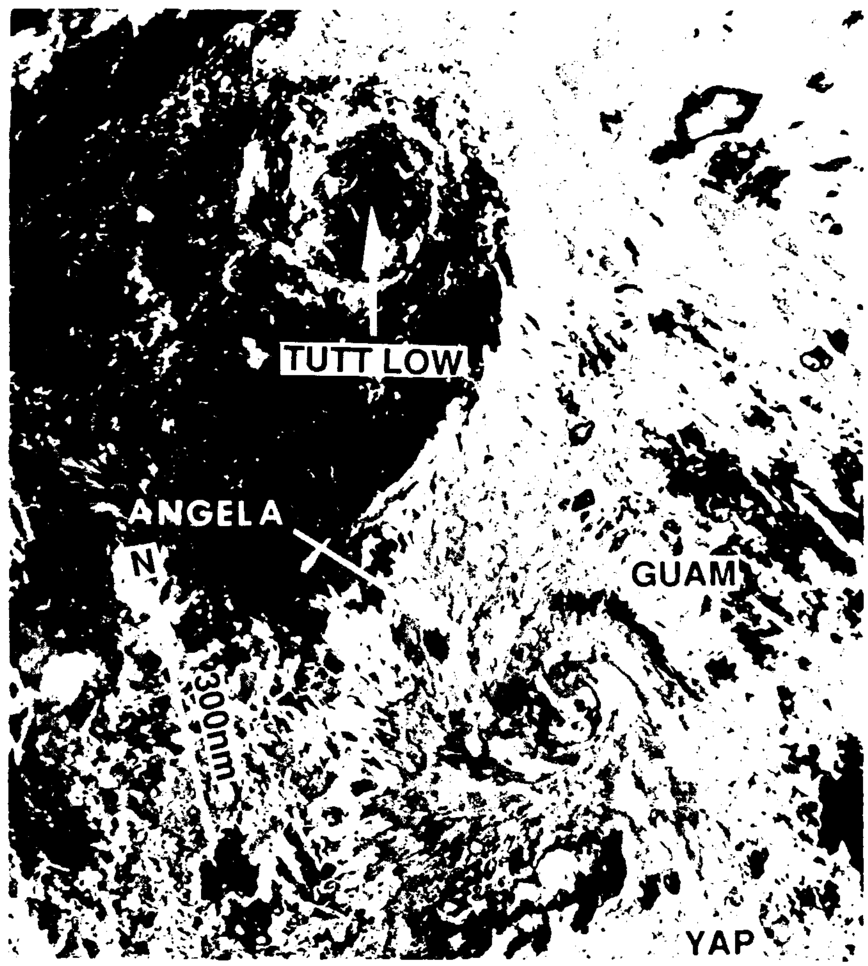


Figure 3-26-1. Angela just after the initial warning was issued. The TUTT low northwest of Angela is enhancing upper-level outflow and divergence (290904Z September DMSP enhanced infrared imagery).

The depression was upgraded to Tropical Storm Angela at 291800Z. Angela initially tracked northwestward, as it developed, influenced by a mid-latitude short wave to the northwest. At 010600Z, the short wave had moved to the east, and Angela started tracking westward along the south side of the subtropical ridge. In the meantime as the short wave approached, Angela developed dual outflow channels and rapid intensification occurred. Angela intensified from 45 kt (23 m/sec) to 90 kt (46 m/sec) during the period 301200Z to 010000Z, reaching typhoon intensity at 301800Z. After 010000Z, intensification was slower as Angela lost the outflow channel to the north. It wasn't until four days later, at 050600Z, that Angela (Figure 3-26-2) was upgraded to a super typhoon.

Between 051500Z and 060300Z, Angela skirted along the northern coast of Luzon and was downgraded to a typhoon at

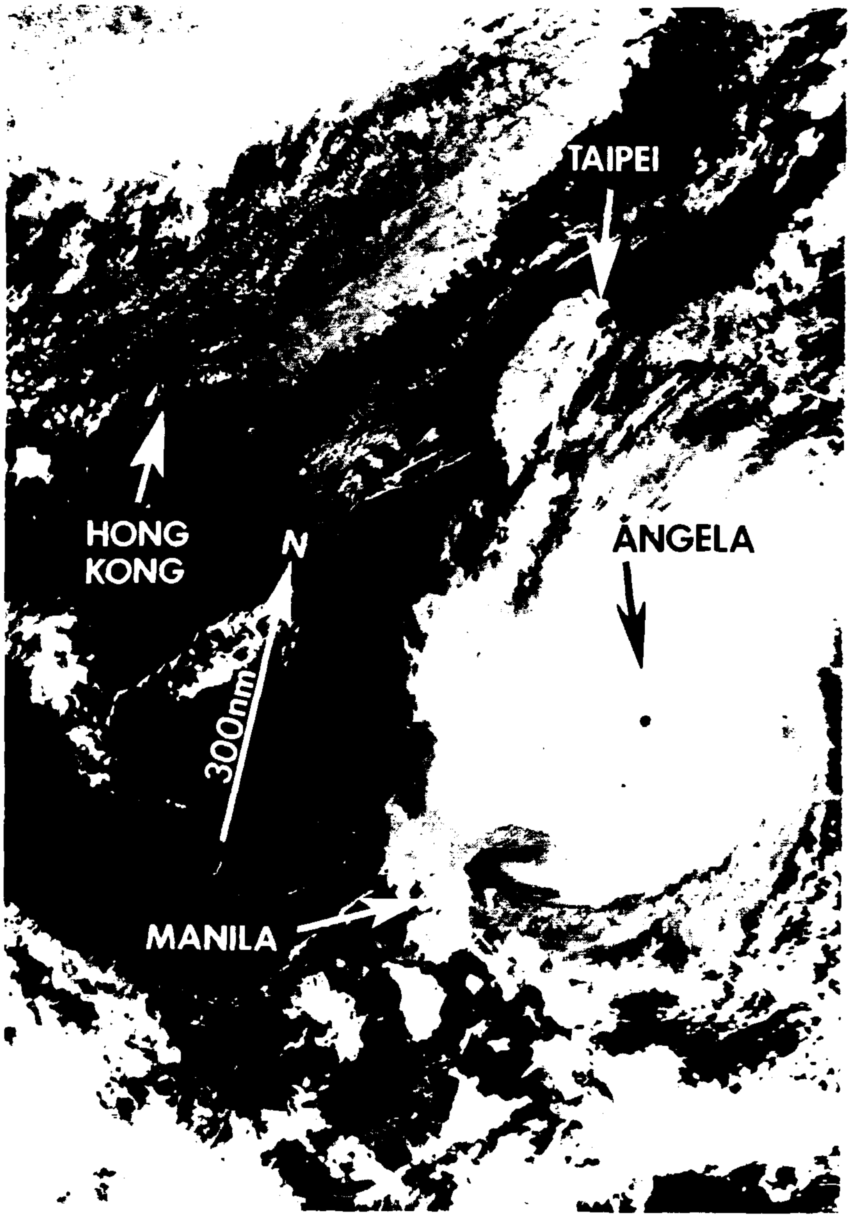
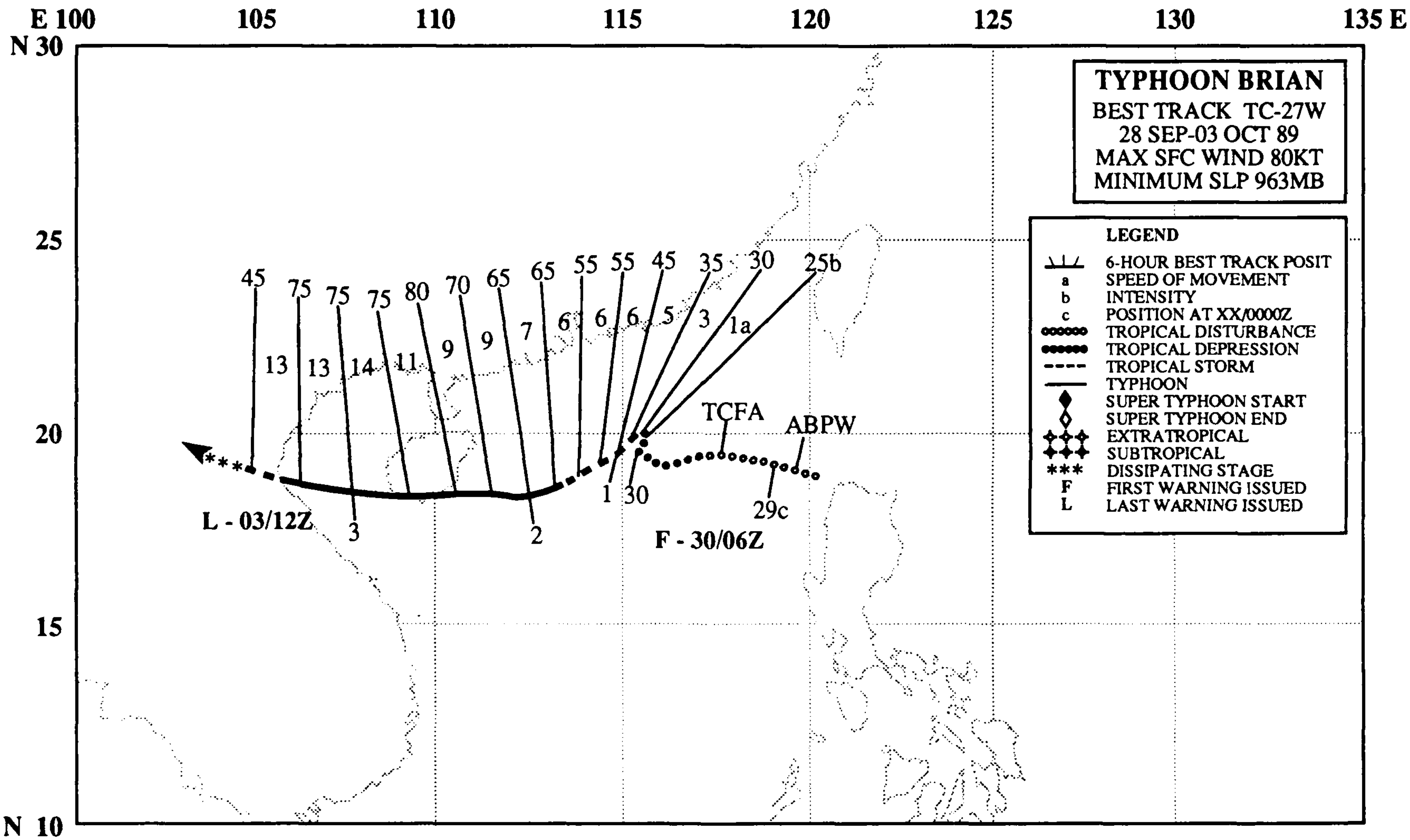


Figure 3-26-2. Super Typhoon Angela at peak intensity just prior to hitting northern Luzon (050558Z October NOAA visual imagery). Note: The spot in the eye is a blemish on the original transparency.

060600Z as it moved into the South China Sea. News reports from the Philippines indicated that the death toll from Angela was 62, mostly drowning victims, with 50 others missing and 21 injured. The high winds and heavy rains triggered flooding and caused heavy damage to crops and infrastructure. Angela destroyed more than 22,000 houses and sent 118,000 people fleeing to evacuation centers.

In the South China Sea, the typhoon started to track west-southwestward with high pressure building over China. As vertical wind shear weakened, Angela reintensified reaching 95 kt (49 m/sec) at 090600Z. Interacting with the topography of Hainan, the typhoon weakened before it moved inland in central Vietnam. At 100600Z, Angela made landfall approximately 30 nm (55 km) north of Hue, Vietnam and the last warning followed at 101200Z.


E 100
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135 E
N 30
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N 10
TYPHOON BRIAN
BEST TRACK TC-27W
28 SEP-03 OCT 89
MAX SFC WIND 80KT
MINIMUM SLP 963MB
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
TCFA
ABPW
29c
30
1
2
3
F - 30/06Z
L - 03/12Z
45 75 75 75 80 70 65 65 55 55 45 35 30 25b
13 13 14 11 9 9 7 6 6 6 5 3 1a

TYPHOON BRIAN (27W)

Typhoon Cecil (04W) in May and Typhoon Brian in late September and early October were the only tropical cyclones of the year to develop and spend their entire lifetimes within the confines of the South China Sea.

As Super Typhoon Angela (26W) developed over the Philippine Sea, the monsoon trough became active across the South China Sea from western Luzon to Vietnam. A broad area of moderate convection developed in the trough and was first mentioned on the 280600Z September Significant Tropical Weather Advisory as a fair suspect area about 390 nm (720 km) southeast of Hong Kong. The satellite signature indicated a well defined upper-level anticyclone, but a weak surface circulation with very little deep convection.

The strong upper-level anticyclone persisted for the next 24 hours and synoptic data indicated that the low-level cyclonic circulation had intensified, prompting the issuance of a Tropical Cyclone Formation Alert at 290830Z. The circulation moved slowly westward along the southern side of the mid-tropospheric subtropical ridge. At 300000Z, the ridge weakened and the disturbance became quasi-stationary 195 nm (360 km) southeast of Hong Kong.

Figure 3-27-1. Tropical Storm Brian tracks toward Hainan (010641Z October NOAA visual imagery).

Over the next six hours, the disturbance drifted northward in an area of weak mid-level steering flow. As JTWC did not expect the depression to intensify during the next 48 hours, a 36-hour Tropical Depression Warning was issued for Tropical Depression 27W at 300600Z. Shortly thereafter, the subtropical ridge strengthened to the north and the depression moved west-southwestward and intensified. Brian (Figure 3-27-1) was upgraded to tropical storm intensity at 301800Z and to typhoon status 24 hours later when it was 240 nm (445 km) southwest of Hong Kong.

On 2 October at 0000Z, Brian (Figure 3-27-2) settled on a westward course and increased its forward speed to 9 kt (17 km/hr). At 021200Z, the typhoon reached a peak intensity of 80 kt (41 m/sec) approximately 20 nm (35 km) off the southeast coast of Hainan Island. Three hours later the cyclone crossed the extreme southern coast of Hainan and weakened to 75 kt (39 m/sec). News releases from the area reported that at least 31 people perished and 500 were injured. In addition, Brian damaged an estimated 190,000 acres (77,000 hectares) of rice.

After mauling Hainan, the typhoon maintained its westward course and 75-kt (39-m/sec) intensity until it made landfall near Vinh, Vietnam. JTWC issued its last warning on Brian at 031200Z. The convection continued westward into the mountains of Vietnam and dissipated the next day.

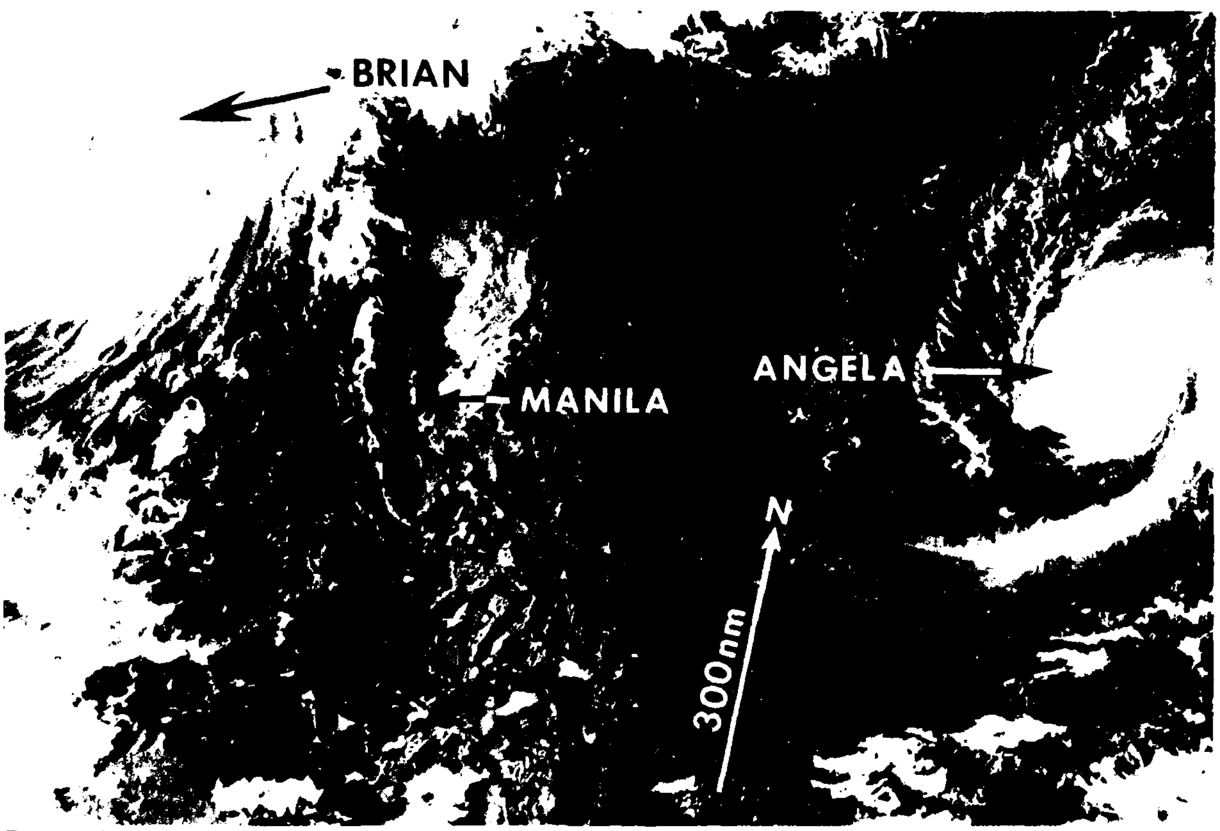

Figure 3-27-2. Typhoons Angela (26W) and Brian. Angela's intensity of 115 kt (59 m/sec) is almost twice that of Brian's (020100Z October DMSP visual imagery).

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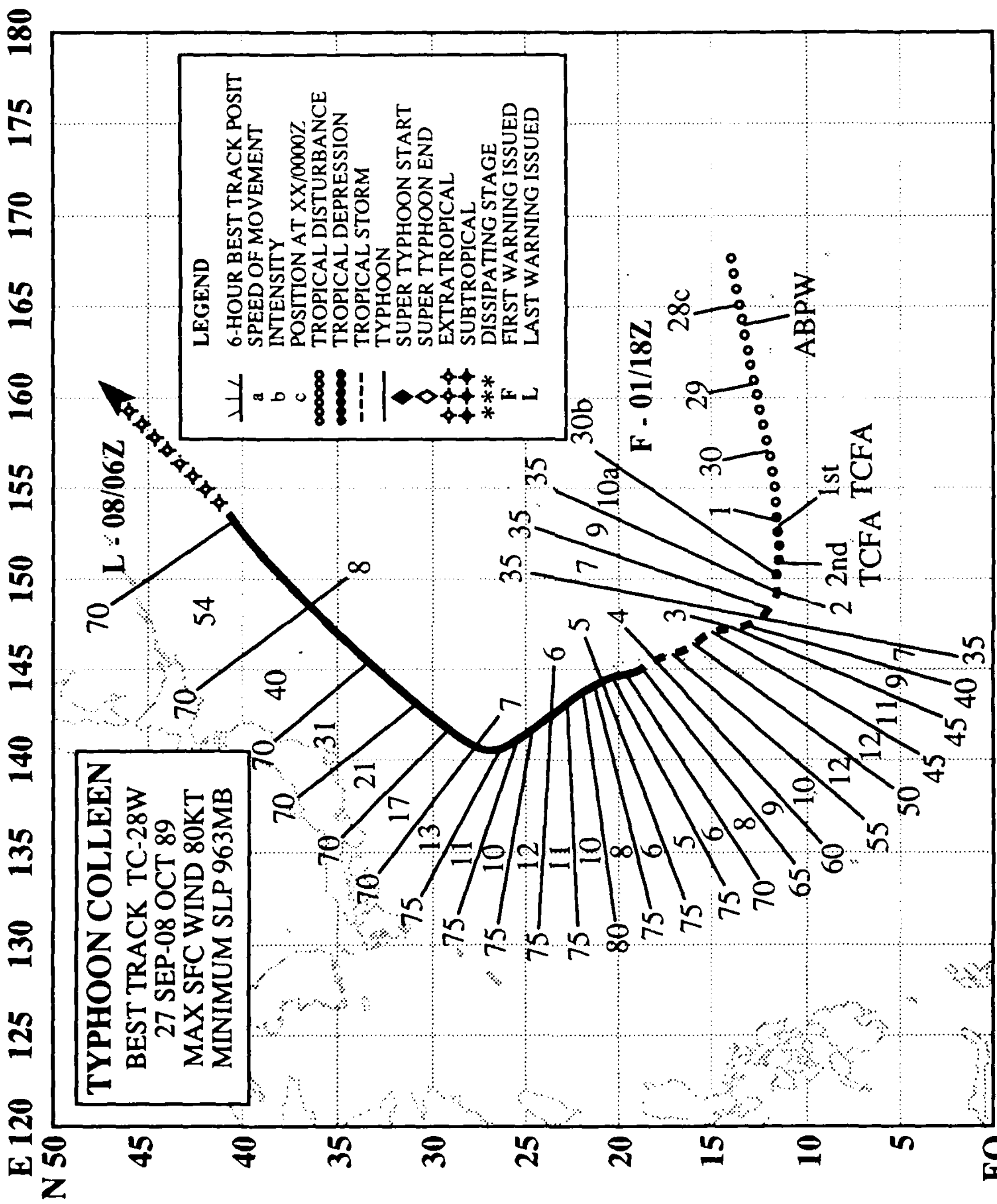
TYPHOON COLLEEN
BEST TRACK TC-28W
27 SEP-08 OCT 89
MAX SFC WIND 80KT
MINIMUM SLP 963MB
LEGEND
6-HOUR BEST TRACK POSIT
SPEED OF MOVEMENT
INTENSITY
POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
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F - 01/18Z
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TYPHOON COLLEEN (28W)

Forming just north of the Marshall Islands, Colleen passed through the northern Mariana Islands before recurving south of Japan. The tropical cyclone maintained typhoon intensity until it completed extratropical transition. Also, Colleen threatened PACEX 89 — the largest US Navy exercise conducted in the Pacific since the Korean War. Colleen underscored the difficulty of tracking poorly organized systems with only nighttime infrared satellite imagery, but also showed the value of the microwave imager data as a tool to help locate these systems.

In the last week of September, Super Typhoon Angela (26W) was forming in the Philippine Sea and Typhoon Brian (27W) in the South China Sea. A deep trough penetrated into the tropical northwestern Pacific near the dateline. An area of cloudiness formed at the base of the trough on 23 September and moved slowly southwestward toward the Marshall Islands. In the data sparse area there were no indications of a surface circulation until 271200Z when pressure falls and wind shifts throughout the northern Marshall Islands reflected the passage of a surface circulation or a tropical wave. JTWC first identified the disturbance as a suspect area on the Significant Tropical Weather Advisory at 280600Z. The disturbance was tracked on the Advisories for the next three days until a Tropical Cyclone Formation Alert was issued at 010030Z October. At that time, based on satellite imagery, the disturbance was analyzed as moving west-northwestward at 15 kt (28 km/hr). Forecasters noted that gradient-level winds at Guam (WMO 91217) had slowly veered from the south-southeast to the west-northwest from 290000Z September until 010000Z October despite the presence of Tropical Storm Angela (26W) to the west of Guam.

The Alert was reissued at 011400Z when satellite analysts determined that the disturbance was moving westward at 9 kt (17

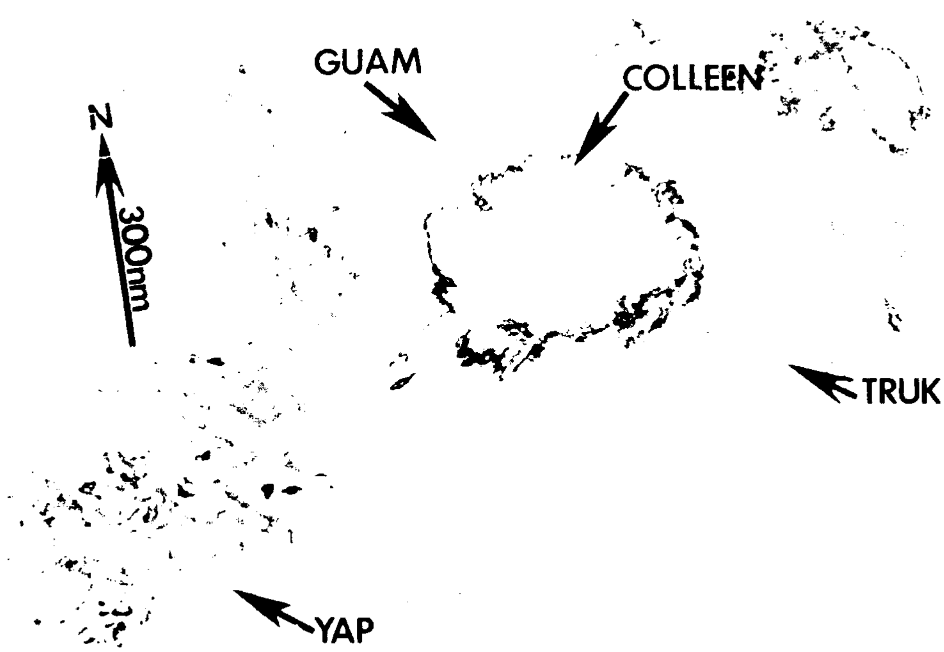

Figure 3-28-1. Tropical Storm Colleen approaching Guam (021159Z October DMSP enhanced infrared imagery).

km/hr). The first warning on Tropical Depression 28W followed at 011800Z after satellite imagery indicated the development of a central dense overcast. The depression was upgraded to Tropical Storm Colleen with the second warning at 020000Z. The forecasts for the initial five warnings called for the system to track south of Guam, however, the accompanying Prognostic Reasoning Messages discussed the possibility of a "stair step" in response to the passage of a short wave trough indicated by the NOGAPS prognostic series.

Tracking Colleen (Figure 3-28-1) became a problem during the night of 2 October. Earlier in the evening, a USAF contractor was installing a computer at Detachment 1, 1WW to process and display DMSP microwave imager information. Between 020800Z and 020900Z, microwave imager data from the 85-gigahertz channel was acquired and processed. These data were able to "see through" the high overcast clouds and the analyst could locate the center of the tropical storm and verify the positions obtained from the infrared channel. Subsequent nighttime infrared positions, without the benefit of the microwave data, indicated that the system was moving west-northwestward in excess of 12 kt (22 km/hr). The 021200Z satellite fix placed the position of the storm within 100 nm (185 km) of Guam, but neither the weather radar at Andersen AFB nor the Air Traffic Control radar operated by the Federal Aviation Administration on Guam could confidently locate the center. Because of the contradictory information presented by the satellite fixes, the lack of central or banding features on radar, and the absence of falling pressures that should accompany a rapidly approaching system, the 021200Z warning position was based only partly on the satellite-derived position. In the post-analysis, the 021200Z satellite position was 96 nm (178 km) west of the final best track position. The average error of the eight infrared satellite fixes made during the night of 2 October was 68 nm (126 km) compared to the 20-nm (37-km) average error for the visual fixes on the 2 and 3 October. Warning number five, valid at 021800Z, was amended at 022300Z and relocated the position of the system to the north based on the first available visual satellite imagery. Also, at that time, 24-hour surface pressure falls at Saipan (WMO 91232) in-

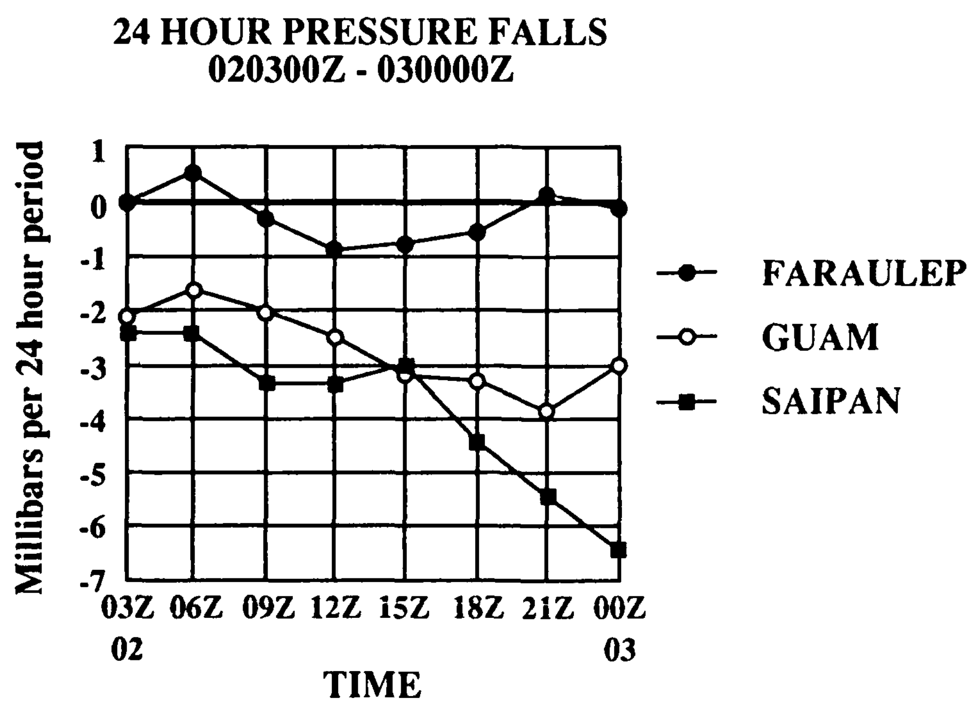

Figure 3-28-2. Twenty-four hour pressure falls at Guam, Saipan, and Faraulep from 020300Z through 030000Z.

creased while Guam (WMO 91212) and the Faraulep AMOS station (WMO 52005) indicated slowing trends (Figure 3-28-2). The relocated position indicated the system had tracked northwestward during the night and was moving towards a weakness in the subtropical ridge. JTWC's amended warning took the system near Saipan in 36 hours. Colleen would eventually pass 120 nm (220 km) to the east of Guam and 30 nm (55 km) to the northeast of Saipan. Colleen tracked northwestward through the northern Marianas (Figure 3-28-3) passing within 60 nm (110 km) of the islands of Pagan and Farallon de Pajaros -- both proposed sites for future Automated Meteorological Observing Stations (AMOS). Heavy rains during Colleen's passage caused widespread flooding on Guam.

Warning number 6, valid at 030000Z, called for the start of recurvature in the vicinity of Iwo Jima near the 72-hour point. However, Colleen slowed to 5 kt (9 km/hr) on 5 October and recurvature was delayed until 061800Z. Subsequent warnings retained the recurvature scenario well south of Japan with significant acceleration to the northeast.

At 040600Z, satellite imagery indicated a partial eyewall, and Colleen was upgraded to a typhoon. The system reached peak intensity at 051200Z -- 210 nm (390 km) southeast of Iwo Jima -- and weakened only slightly as it headed for its recurvature point. Ships involved in PACEX 89 altered course to avoid any encounter with Colleen. After 061800Z, the tropical cyclone moved northeastward and weakened to 70 kt (36 m/sec). Colleen maintained its intensity but doubled its speed of movement to 21 kt (39 km/hr) during the next 18 hours, and almost doubled it again to 40 kt

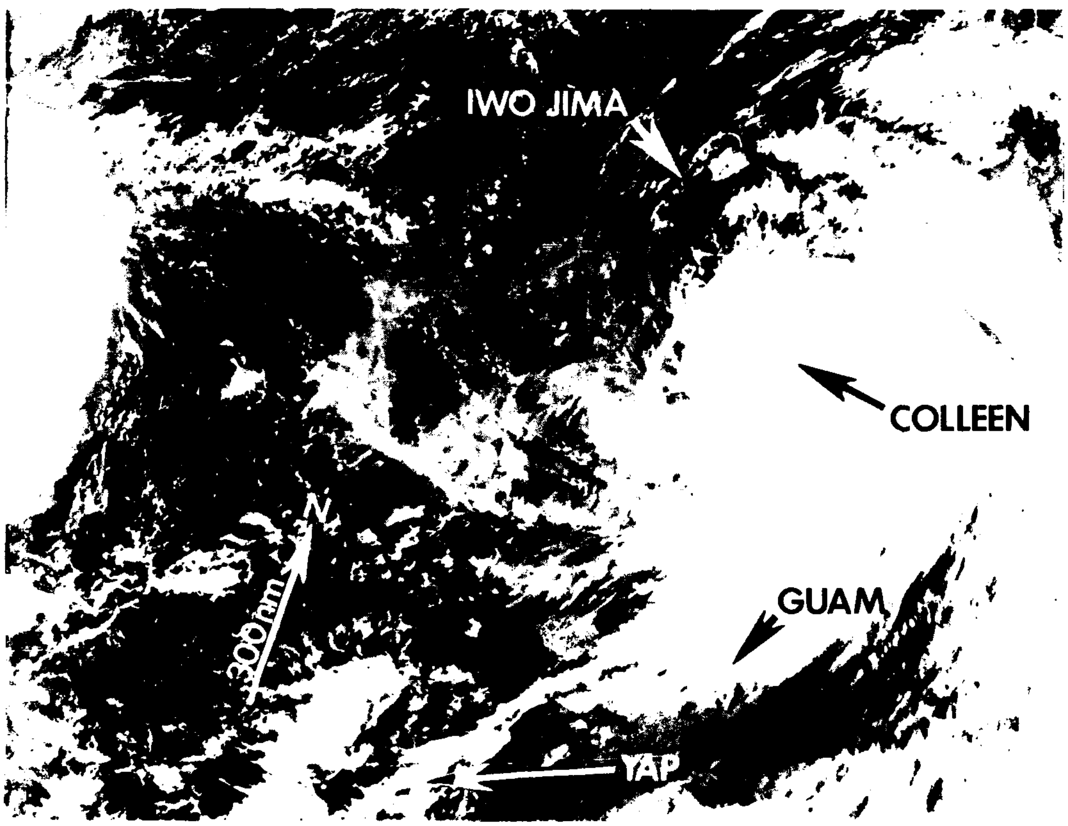

Figure 3-28-3. Typhoon Colleen leaving the northern Marianas. The cloud mass on the left is Typhoon Angela (26W) (042358Z October DMSP visual imagery).

(74 km/hr) during the following 12 hours.

JTWC issued its final warning at 080600Z (Figure 3-28-4) when Colleen was approximately 660 nm (1220 km) east of northern Honshu moving at 54 kt (100 km/hr) to the northeast and still packing sustained winds of 70 kt (36 m/sec). It became one of the most intense extratropical cyclones of the year. In satellite imagery at 081200Z the extratropical remnants of Colleen were discernible near 46° north latitude.

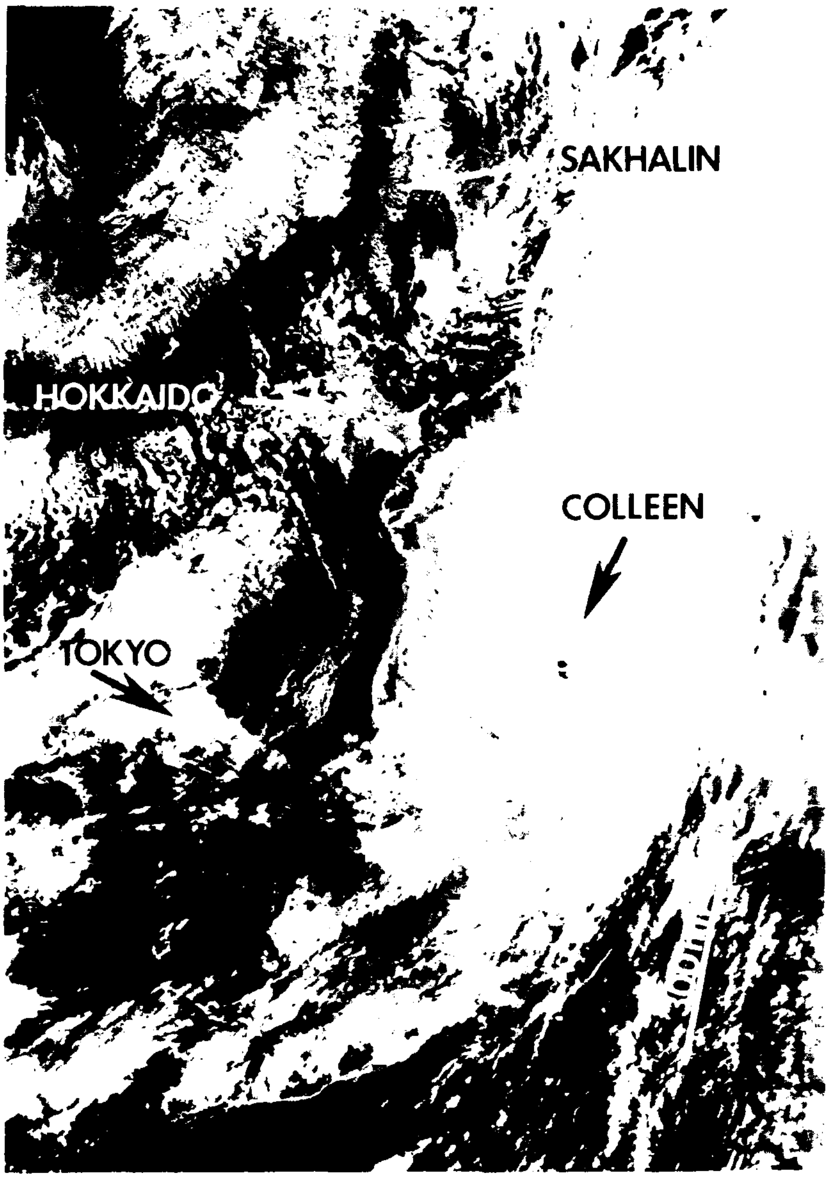

Figure 3-28-4. Typhoon Colleen undergoing extratropical transition (080344Z October NOAA visual imagery).

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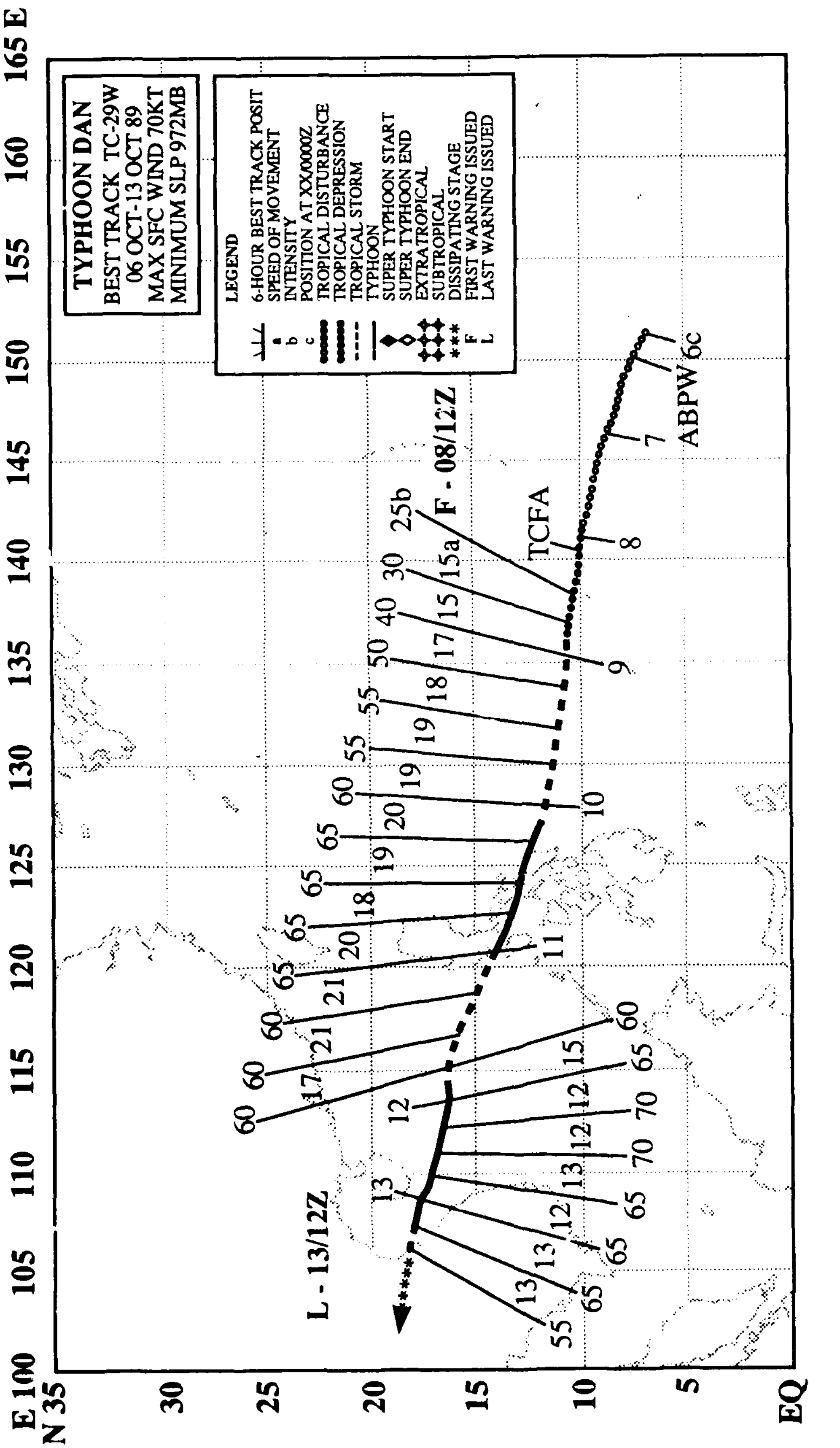

TYPHOON DAN
BEST TRACK TC-29W
06 OCT-13 OCT 89
MAX SFC WIND 70KT
MINIMUM SLP 972MB
LEGEND
6-HOUR BEST TRACK POSIT
SPEED OF MOVEMENT
INTENSITY
POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
F - 08/12Z
L - 13/12Z
TCFA
ABPW
E 100
N 35
165 E
EQ

TYPHOON DAN (29W)

Forming in October in the Caroline Islands near Truk, Dan followed a steady west-northwestward track and crossed the central Philippine Islands. Coming just days after Typhoon Angela's (26W) destructive passage through northern Luzon, Dan had a devastating effect on southern Luzon. The cyclone reintensified in the South China Sea and made landfall on the coast of central Vietnam where it caused more destruction.

On 6 October a disturbance formed in the monsoon trough near Truk in the central Caroline Islands. JTWC evaluated the weak low-level circulation center and its divergent flow aloft. On the Significant Tropical Weather Advisory at 060600Z, in light of strong vertical wind shear affecting the disturbance, JTWC classified it as having poor potential for development. After the disturbance persisted for another day, the potential was upgraded to fair. On 8 October, weaker vertical wind shear and the presence of a well-developed band of convection near the low-level circulation center led to the issuance of a Tropical Cyclone Formation Alert at 0330Z.

At 081200Z , JTWC issued the first warning on Tropical Depression 29W which was located 60 nm (110 km) northeast of Yap in the western Caroline Islands. Eighteen hours later, the depression was upgraded to Tropical Storm Dan. The moderate flow south of the mid-level subtropical ridge axis kept the system on a 15- to 20-kt (28- to 37-km/hr) west-northwestward course toward the central Philippine Islands. Deep convection continued to improve with upper-level outflow efficient in all but the northwest quadrant, where it was restricted by the outflow from Typhoon Angela (26W). After outflow in the northwest improved and the eye become visible, Dan was upgraded to a typhoon at 100600Z.

At 101300Z, Typhoon Dan made landfall on the extreme southeastern coast of Luzon and later passed 20 nm (37 km) south of Manila's Ninoy Aquino International Airport (WMO 98429). The weather station reported sustained winds of 45 kt (23 m/sec) with gusts to 65 kt (33 m/sec). The strong winds rearranged some of the aircraft parked on the tarmac, blowing an Omani Boeing 707 and a Bangladesh presidential DC-10 into each other. Forty-eight nm (90 km) north of Manila, Clark AB (WMO 98327) received winds of 30 kt (15 m/sec) with gusts to 50 kt (26 m/sec) from 110100Z to 110400Z. Cubi Point NAS (WMO 98426), 40 nm (75 km) northwest of Manila, reported sustained winds of 40 kt (21 m/sec) with gusts to 75 kt (39 m/sec). From 100000Z to 120000Z Cubi Point reported 5 inches (125

mm) of rain, while Clark AB measured 3.5 inches (90 mm).

As Dan moved into the South China Sea, it lost its eye feature and weakened to tropical storm intensity at 110300Z (Figure 3-29-1). Tracking west-northwestward over the warm sea, the cyclone regained its convection, reformed its eye, and was again upgraded to a typhoon at 120000Z. Dan reached a peak intensity of 70 kt (36 m/sec) six hours later. The typhoon weakened slightly as it approached and passed 60 nm (110 km) to the south of Hainan Island. As Dan approached the coast of central Vietnam, increased mid- to upper-level shear elongated the cloud shield and weakened the system. Dan made landfall on the central coast of Vietnam at 131200Z, and at that time JTWC issued a final warning. The circulation dissipated in the mountains and the disorganized convection continued westward into Laos.

Dan, despite being only a minimal typhoon, proved to be a very destructive one. In the Philippines the Department of Social Welfare reported at least 41 people killed; 16,185 houses damaged; and. 232,555 left homeless or without livelihoods. Electrical power was lost to 95% of Metropolitan Manila because of downed power lines; "brown-outs" continued for weeks afterward. In Vietnam, Dan ripped the roofs off buildings, downed communication lines, and flooded over 320,000 acres.

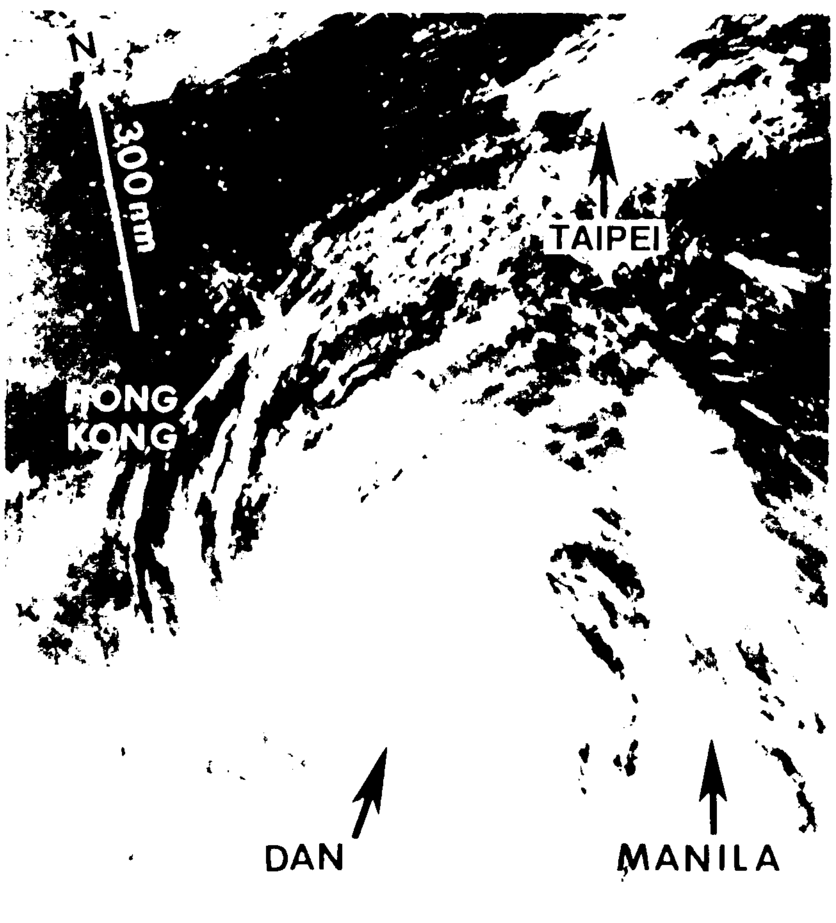

Figure 3-29-1. Moonlit photo of Typhoon Dan as it enters the South China Sea and the eye reforms (111348Z October DMSP visual imagery).

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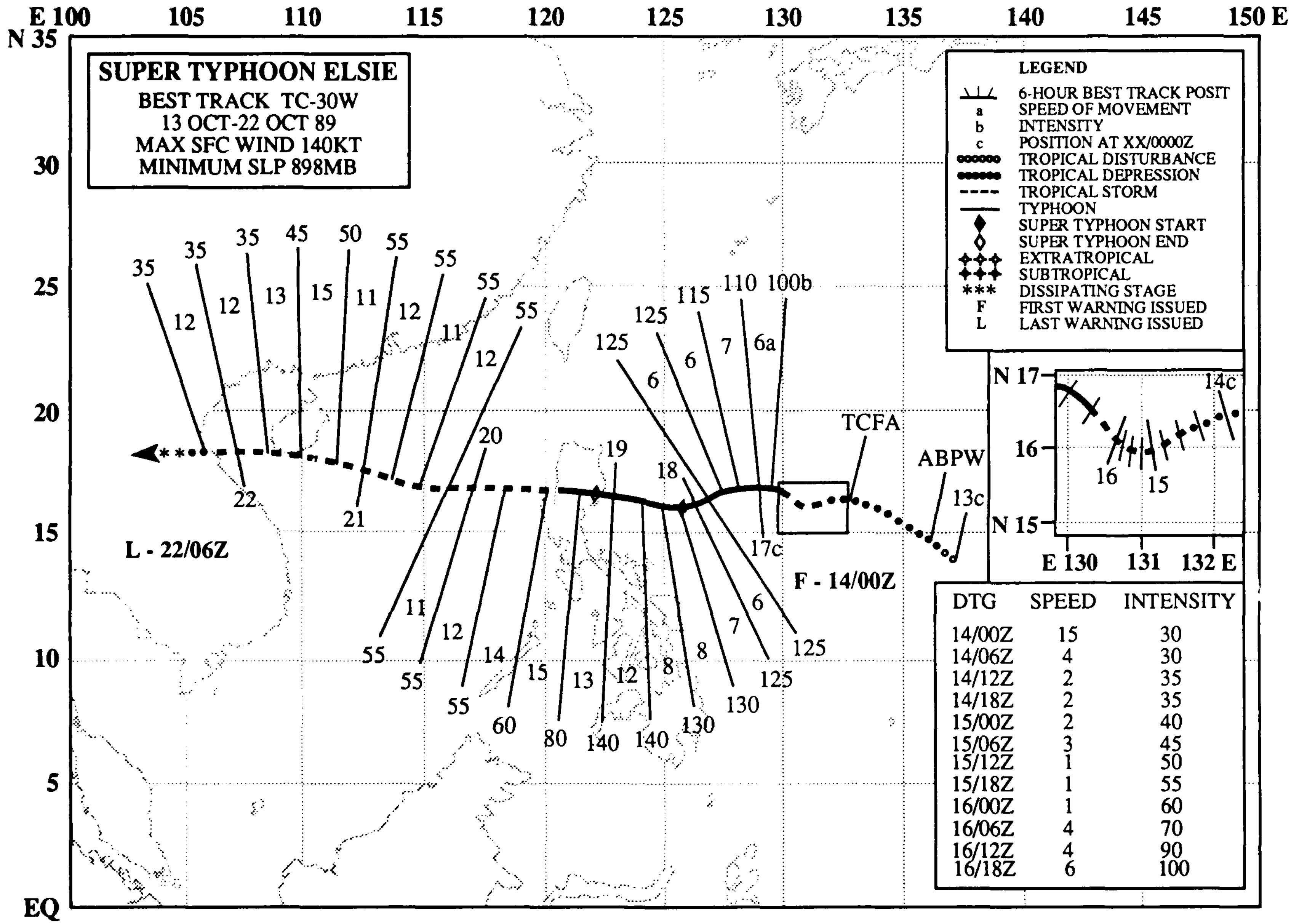

DTG	SPEED	INTENSITY
14/00Z	15	30
14/06Z	4	30
14/12Z	2	35
14/18Z	2	35
15/00Z	2	40
15/06Z	3	45
15/12Z	1	50
15/18Z	1	55
16/00Z	1	60
16/06Z	4	70
16/12Z	4	90
16/18Z	6	100

SUPER TYPHOON ELSIE (30W)

In the wake of Super Typhoon Angela (26W) and Typhoon Dan (29W), Super Typhoon Elsie became the third tropical cyclone to hit the Philippine Islands within 12 days. Elsie developed from a TUTT-induced wave in the easterlies and tracked westward throughout its life. In the Philippine Sea, Elsie rapidly intensified and struck central Luzon with an intensity of 140 kt (72 m/sec). In news reports it was cited as the most intense cyclone to strike the Philippine Islands this year. Elsie weakened dramatically as it moved across the Philippines, and did not reintensity as it traversed the South China Sea. The cyclone dissipated after making landfall in central Vietnam.

In the middle of October the Tropical Upper Tropospheric Trough (TUTT) was well established in a east-west orientation across the western North Pacific. As Typhoon Dan (29W) made landfall in central Vietnam, a tropical disturbance developed approximately 670 nm (1240 km) east-northeast of Manila and started tracking west-northwestward. The system, first mentioned on the Significant Tropical Weather Advisory at 130600Z, was located between two small TUTT lows -- one located to the southwest and one located to the northeast of the disturbance. These TUTT lows enhanced the disturbance's upper-level outflow, and at 132330Z a Tropical Cyclone Formation Alert was issued. As the disturbance intensified, the first warning was issued on Tropical Depression 30W at 140000Z, followed by an upgrade to Tropical Storm Elsie at 141200Z. At that time, Elsie stalled as it moved into an area of weak steering flow between two subtropical highs.

Late on 15 October, Elsie began a "stair step" northwestward, as a mid-latitude short wave passed to the north. This short wave enhanced the outflow, and Elsie rapidly intensified from 60 kt (31 m/sec) to 110 kt (57 m/sec) in 24 hours. At 160600Z, Elsie was upgraded to a typhoon and became a super typhoon at 180600Z. Super Typhoon Elsie (Figure 3-30-1) reached its maximum intensity of 140 knots (72 m/sec) at 181800Z and then

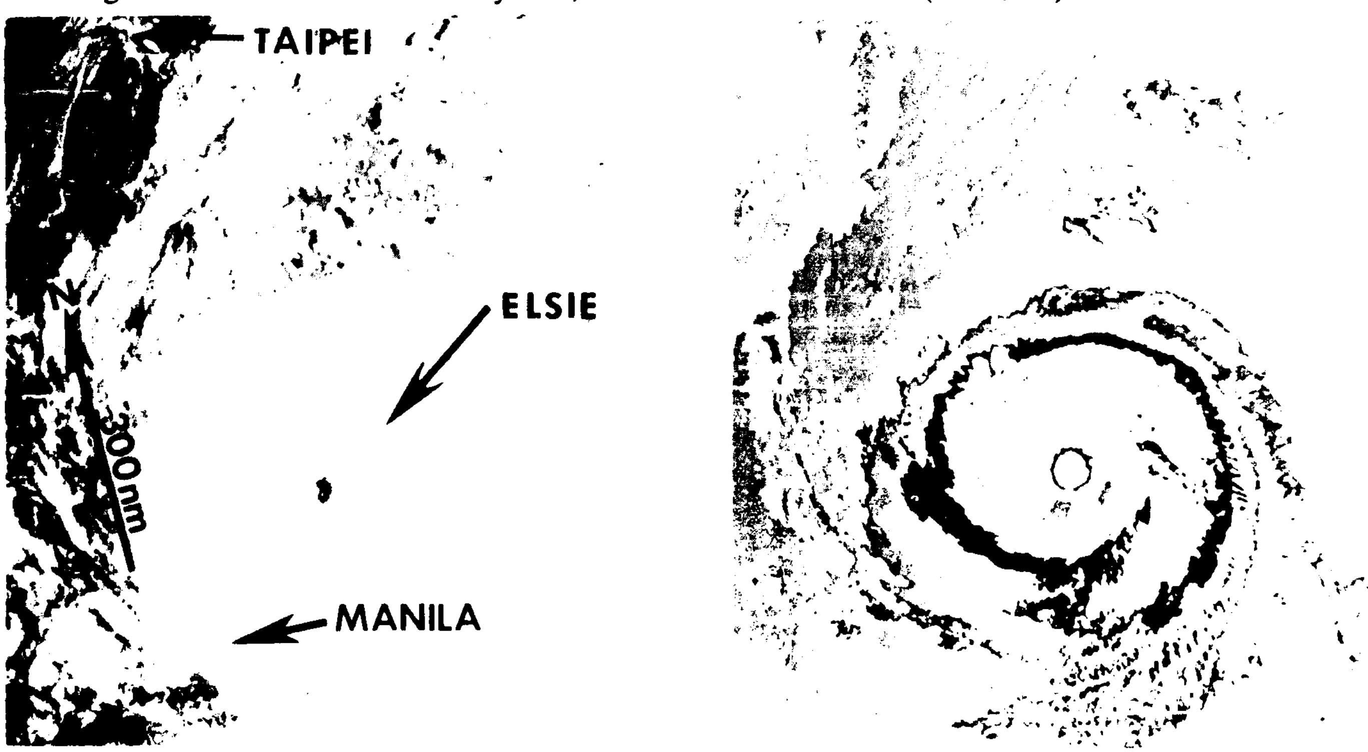

Figure 3-30-1. A matched pair of enhanced infrared (left) and visual (right) data show Elsie's classic cloud-free eye and surrounding central dense overcast (190000Z October NOAA visual and infrared imagery).

made landfall in central Luzon at 190300Z.

As it crossed Luzon, Elsie weakened rapidly due to frictional effects and the loss of oceanic sensible and latent heat sources . The system was downgraded to a typhoon at 190600Z, and then to a tropical storm at 191200Z. The tropical cyclone tracked westward along the south side of a northeast monsoonal surge. Vertical wind shear associated with the surge prevented Elsie from reintensifying in the South China Sea (Figure 3-30-2). The final warning was issued at 220600Z as Tropical Storm Elsie made landfall in central Vietnam. The remnants remained identifiable until they reached the mountainous terrain of Laos.

In the Philippines Super Typhoon Elsie left at least 17 dead, 50,000 homeless, and damage in the millions of dollars. John Hay Air Station and Wallace Air Station sustained a total of $30,000 damage, including damaged roofs, uprooted trees and destroyed sheds.

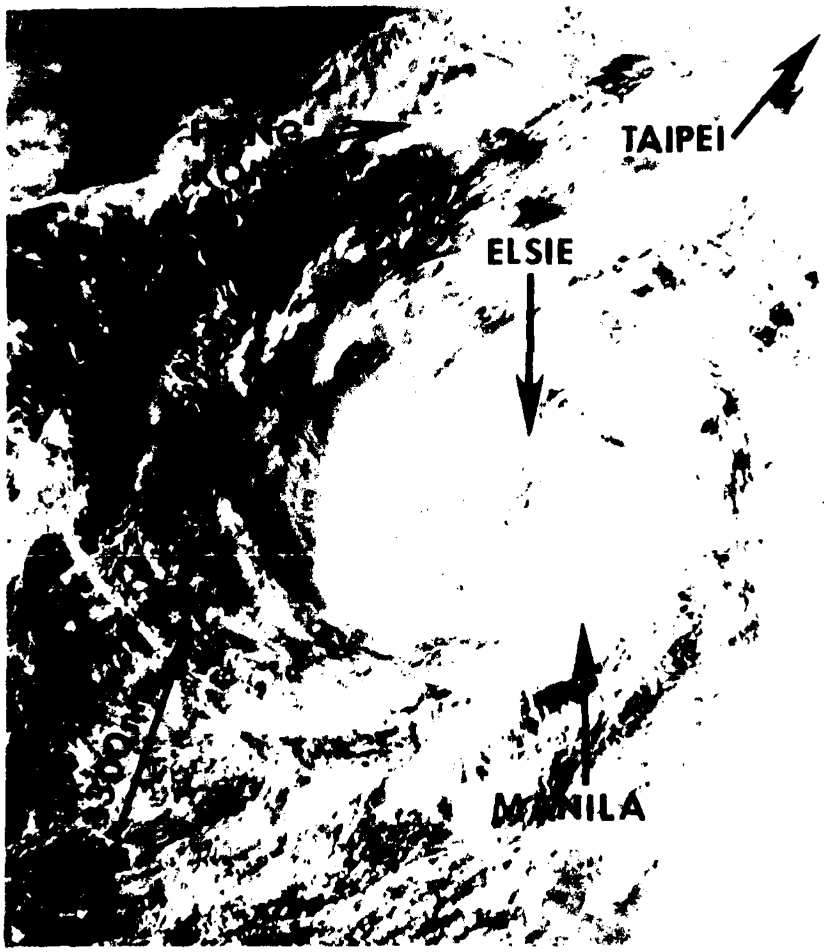

Figure 3-30-2. Elsie spins westward across the South China Sea and never regains typhoon intensity (192233Z October DMSP visual imagery).

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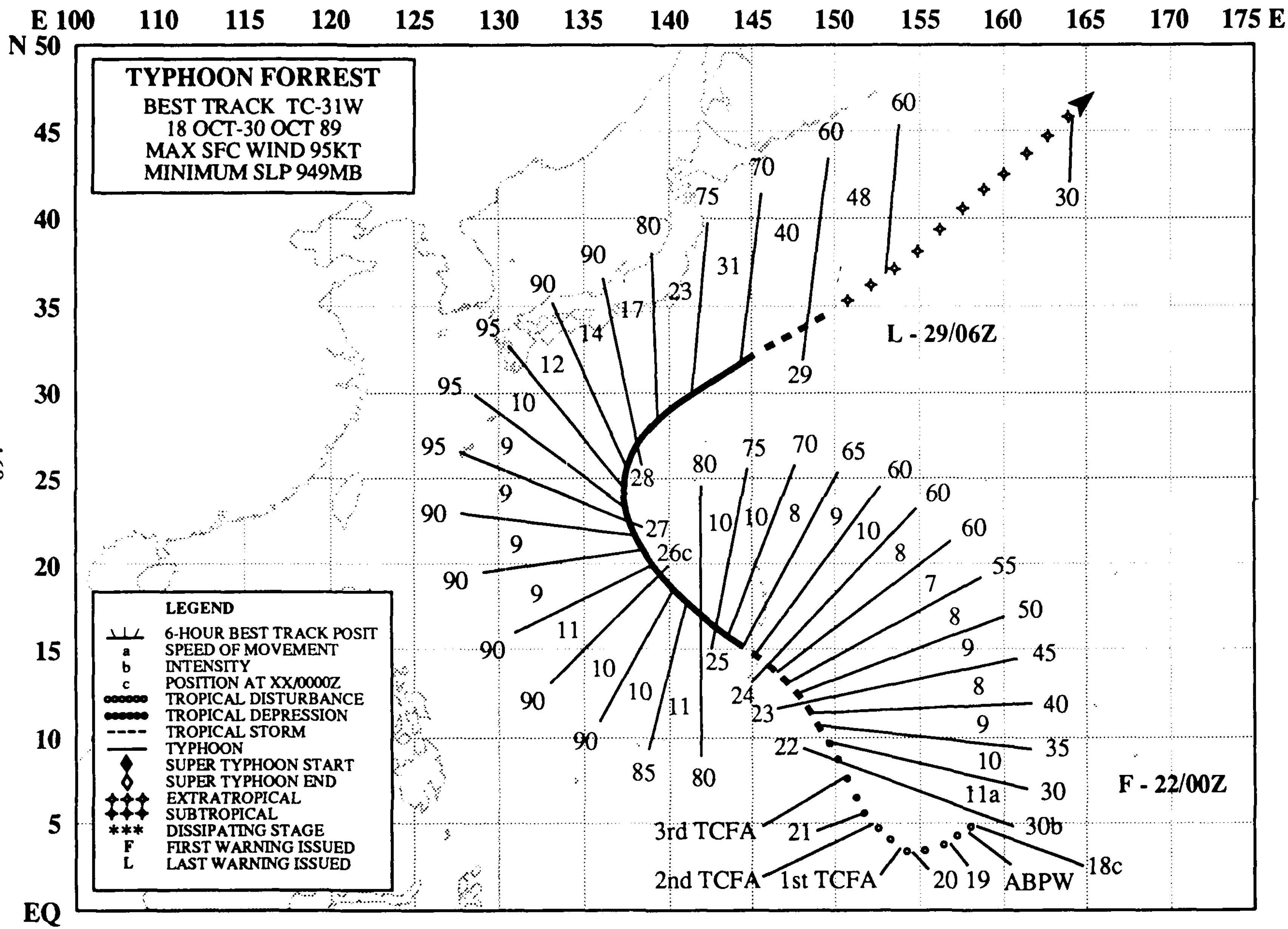


TYPHOON FORREST
BEST TRACK TC-31W
18 OCT-30 OCT 89
MAX SFC WIND 95KT
MINIMUM SLP 949MB
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 29/06Z
F - 22/00Z
3rd TCFA
2nd TCFA
1st TCFA
ABPW
E 100
110
115
120
125
130
135
140
145
150
155
160
165
170
175 E
N 50
45
40
35
30
25
20
15
10
5
EQ

TYPHOON FORREST (31W)

The last of six tropical cyclones in October and the 17th typhoon of the year, Forrest was slow and erratic in its development. In fact, JTWC issued and reissued three Tropical Cyclone Formation Alerts before finally disseminating the first warning on Tropical Depression 31W. Throughout its early life, Forrest was a sloppy, broad system with large diurnal variations in its convection. After passing Guam, Forrest finally intensified and ultimately became a 95-kt (49- m/sec) typhoon. Soon thereafter, it recurved and accelerated rapidly to the northeast, becoming one of the year's strongest extra-tropical cyclones in the Pacific. Forrest's track was striking in its similarity to the track of Typhoon Colleen (28W).

As Super Typhoon Elsie (30W) approached the northern Philippines on 17 October, the near-equatorial trough reestablished itself through the Marshall and eastern Caroline Islands and generated a tropical disturbance. JTWC initially discussed the disturbance located about 100 nm (185 km) south of Pohnpei on the Significant Tropical Weather Advisory on 18 October. During the next two days, the disturbance moved toward the west-southwest. Then on the morning of 20 October, it took a turn to the northwest approximately 180 nm (335 km) southeast of Truk. At 200200Z, JTWC issued the first of three Tropical Cyclone Formation Alerts, when the apparent cloud rotation on animated cloud imagery changed from anticyclonic to cyclonic, indicating the development of organized deep convection. From 20 to 22 October, the disturbance (Figure 3-31-1) underwent extremely large diurnal fluctuations in convection creating a broad circulation center and slowing intensification. The disturbance passed about 45 nm (85 km) west of Truk in the evening of 21

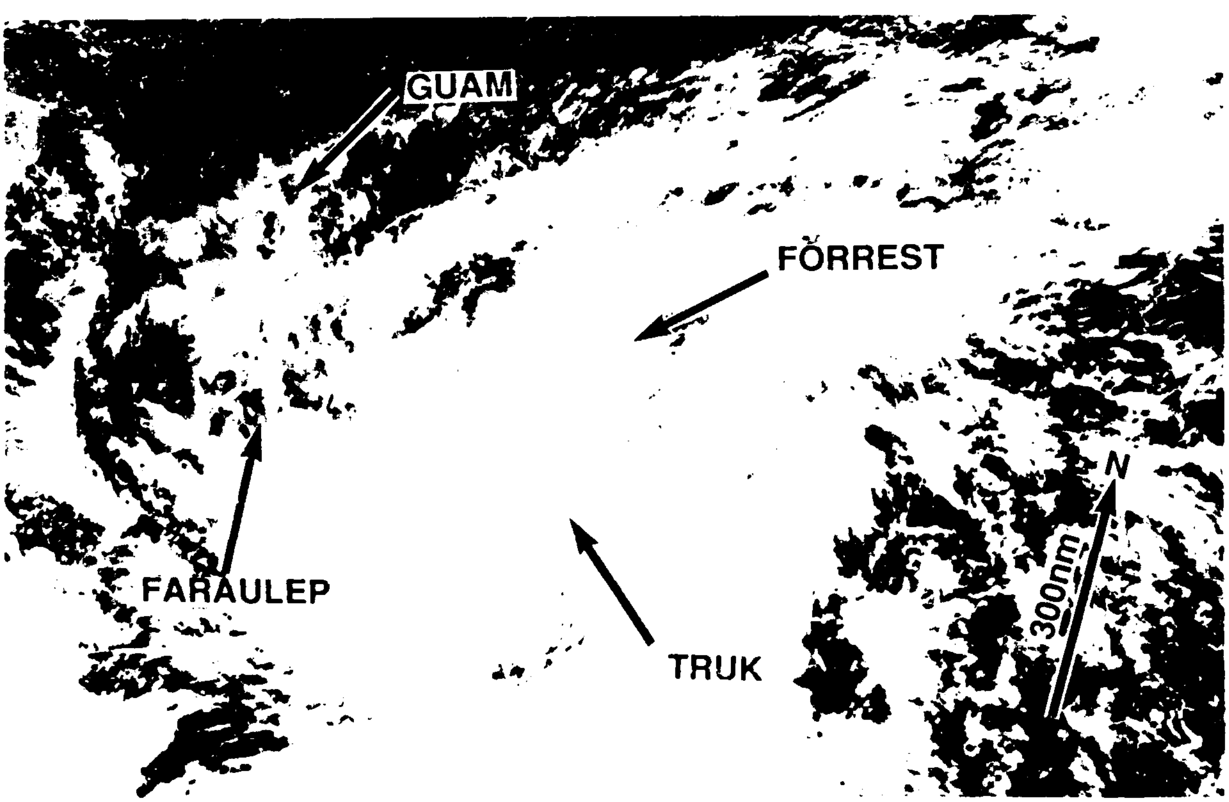


Figure 3-31-1. Forrest prior to the first warning shows a large, poorly defined circulation center (212315Z October DMSP visual imagery).

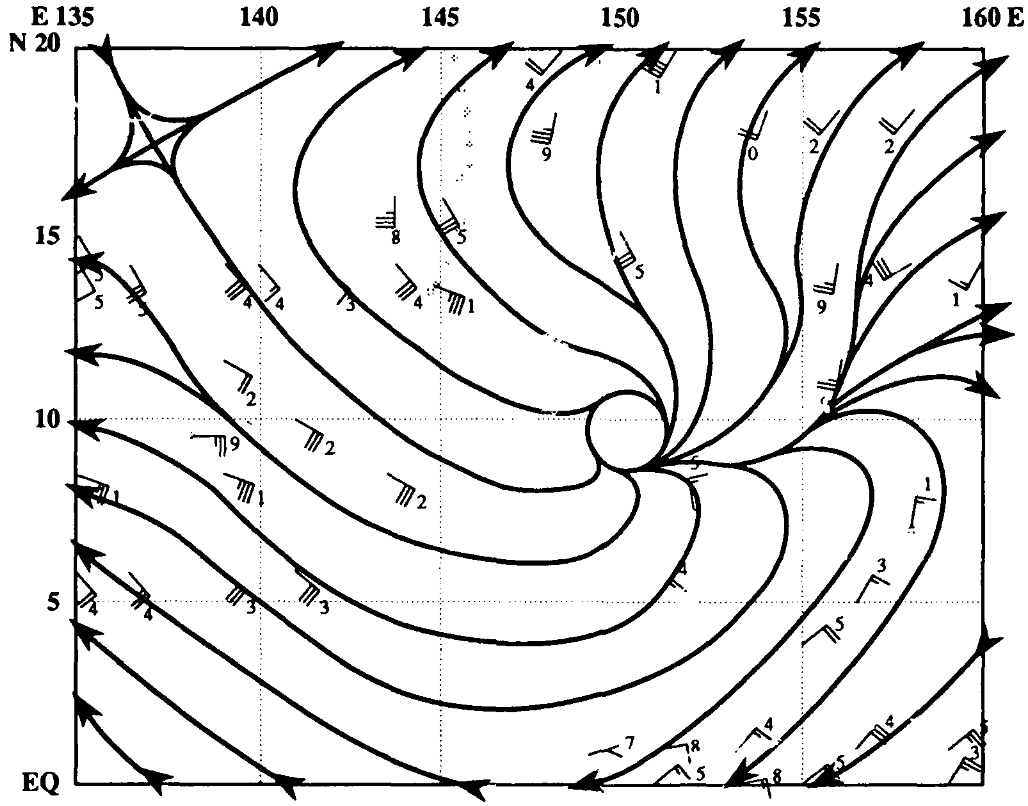
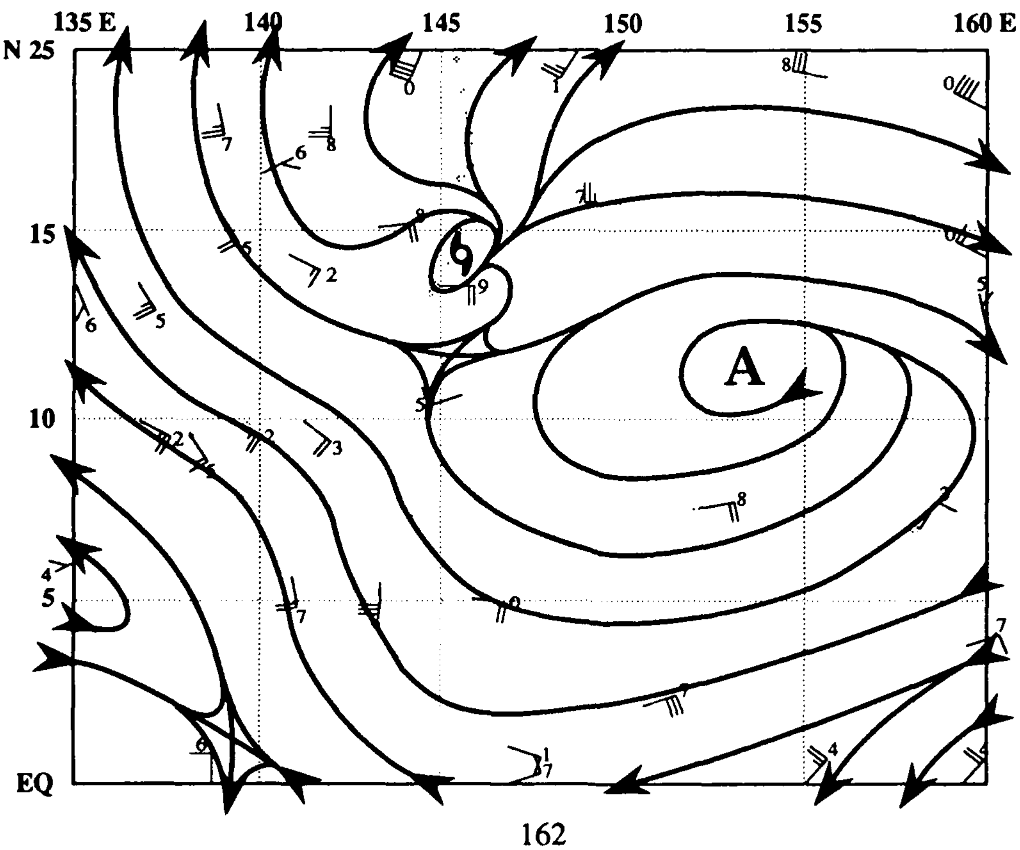


Figure 3-31-2. (a) 230000Z October 200 mb composite streamline analysis showing unrestricted outflow channels to the north and south. (b) 231200Z October 200 mb composite analysis showing the large anticyclone southeast of Forrest's main upper-level circulation center.



October. From 212100Z to 230900Z, Truk experienced sustained 20 to 25 kt (10 to 13 m/sec) surface winds from the monsoon surge associated with the disturbance. At 222000Z, the first warning was issued on Tropical Depression 31W as it reached 30 kt (15 m/sec) and developed efficient outflow channels to the north and south. Twelve hours later, the depression was upgraded to a tropical storm. Forrest moved toward the northwest and intensified at a rate of 5 kt (3 m/sec) every 6 hours. Forecasters at JTWC expected Forrest to reach typhoon intensity as it approached Guam and to rapidly intensify 24 hours later. However, on 23 October the southern outflow channel was completely severed as a large upper-level anticyclone developed to the south of the cyclone (Figure 3-31-2) as a result of the vigorous convection in the rainband to the southeast (Figure 3-31-3). This, coupled with

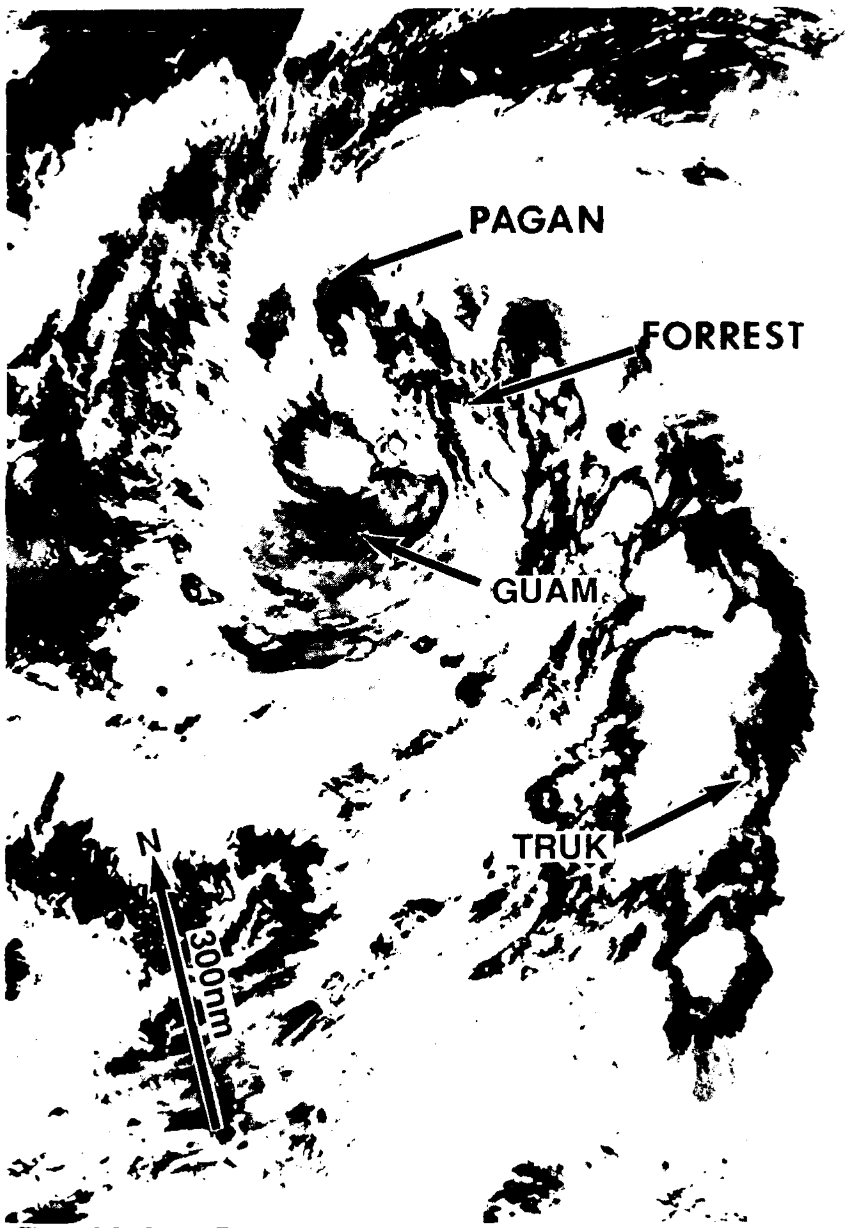


Figure 3-31-3. As Forrest nears Guam, a wide ribbon of deep convection to the southeast of the center contrasts with small area of central convection (232207Z October NOAA visual imagery).

the normal tendency for suppressed daytime convection, resulted in a convectively inactive, broad circulation center. Without the organized convection, winds remained relatively strong aloft, but weak at the surface, especially over land. At 240800Z, Forrest passed within 75 nm (140 km) of the International Airfield on Guam. The weather station (WMO 91212) recorded gusts to 34 kt (18 m/sec) and a minimum sea level pressure of 998 mb. Strong vertical wind shear the following day did ground aircraft on Guam and Saipan. During the day, convection remained disorganized, but about 8 hours after passing Guam, convection rapidly increased and Forrest, which was close to Saipan, intensified and formed a banding type eye. Even though the typhoon was moving away from Saipan, it buffeted the island with moderately strong winds, downing tree limbs and power lines. The airport at Saipan (WMO 91232) recorded a

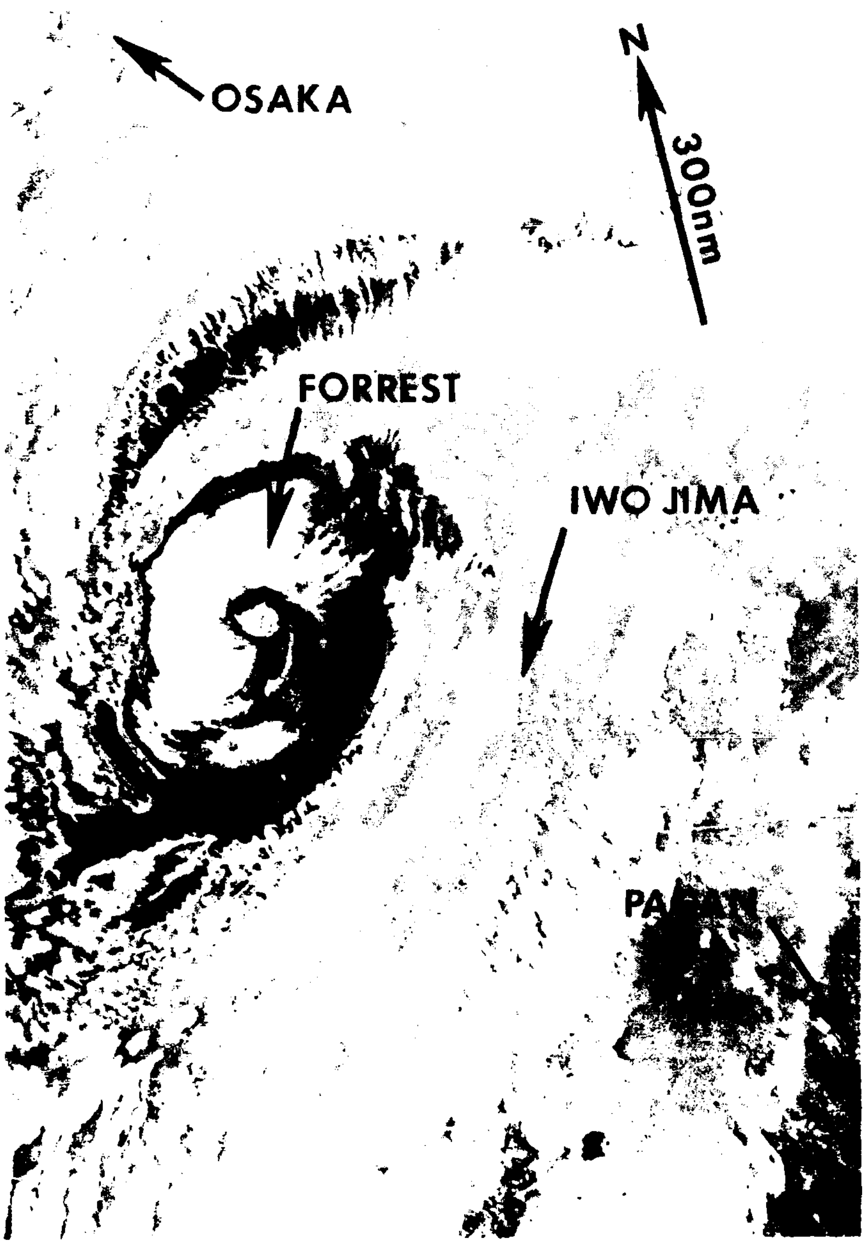
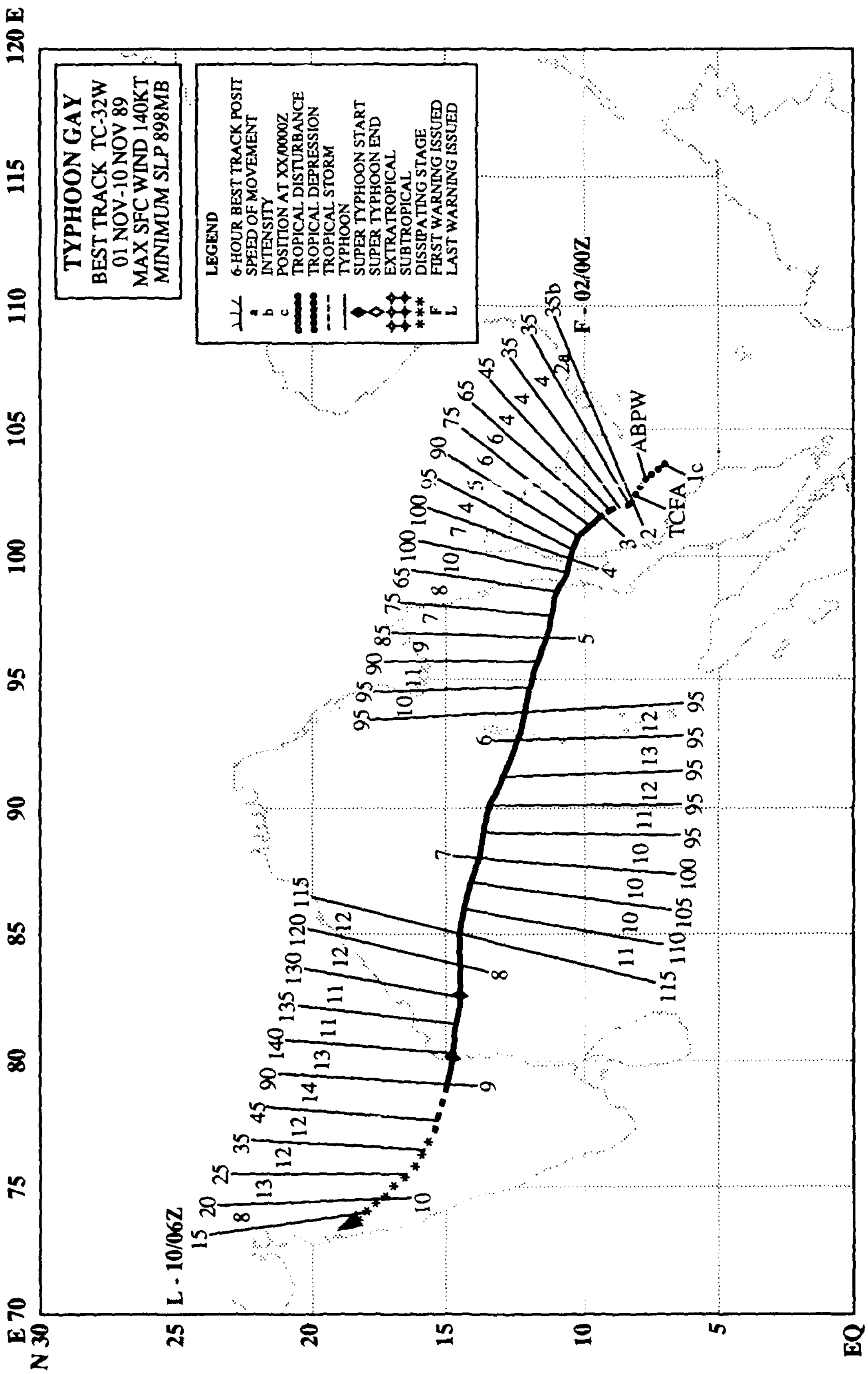


Figure 3-31-4. Enhanced infrared image of Typhoon Forrest at peak intensity (271632Z October NOAA infrared imagery).

minimum pressure of 991 mb at 250400Z, several hours after Forrest had passed. Capitol Hill at an elevation of 1000 ft (305 m) above sea level unofficially recorded wind gusts to 50 kt (26 m/sec). Reports stated that Forrest left most of the island without power, stopped air travel, closed schools, and flooded low-lying areas.

The typhoon continued its northwestward track at an average speed of 10 kt (19 km/hr). Twelve hours prior to recurvature, Forrest attained its peak intensity of 95 kt (49 m/sec) as it crossed the axis of the mid-tropospheric sub-tropical ridge (Figure 3-31-4). Following recurvature at 271200Z, the cyclone began to accelerate to the northeast. On the evening of 26 October, a typhoon acceleration prediction technique (Weir, 1982) used to help determine the timing of recurvature and acceleration indicated that Forrest was about to recurve, and that it would rapidly accelerate. In response, JTWC altered its forecast considerably to reflect the anticipated changes. This caused the **USS Carl Vinson** battle group to alter its course from one passing across the storm's expected track to one that kept it northwest of that track off the coast of Japan. While recurvature and acceleration were delayed 12 to 18 hours making and the speed of JTWC's forecast too fast, the direction forecast was correct. Remaining over relatively warm water and maintaining an efficient outflow channel into the mid- latitude westerlies, Forrest did not rapidly weaken. At 281200Z, the typhoon had accelerated to nearly 30 kt (56 km/hr), and still packed 75-kt (39-m/sec) winds, partly as a result of its rapid motion along track. At this time, Forrest passed within 175 nm (325 km) to the northwest of Chichijima (WMO 47971) where 850 mb winds were recorded at 230 degrees at 65 kt (33 m/sec). Interacting with the mid-latitude westerlies, Forrest's convective heat engine finally gave way to baroclinic energy-producing processes and the storm became extratropical while moving northeastward at nearly 50 kt (93 km/hr). The final warning on Typhoon Forrest was issued at 290600Z. Like Colleen, the resulting extratropical system became one of the strongest winter storms in the Pacific during 1989, packing storm force winds in excess of 60 kt (31 m/sec).



TYPHOON GAY
BEST TRACK TC-32W
01 NOV-10 NOV 89
MAX SFC WIND 140KT
MINIMUM SLP 898MB
LEGEND
6-HOUR BEST TRACK POSIT
SPEED OF MOVEMENT
INTENSITY
POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
F - 02/00Z
L - 10/06Z
ABPW
TCFA
120 E
115
110
105
100
95
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85
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E 70
N 30
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EQ

TYPHOON GAY (32W)

The first tropical cyclone of November turned out to be the worst tropical cyclone to affect the Malay Peninsula in 35 years. Gay developed in the Gulf of Thailand, crossed the Malay Peninsula into the Bay of Bengal and slammed into India with peak sustained winds of 140 kt (70 m/sec). Unique because of its small size, intensity, and point of origin, Gay challenged forecasters by crossing two different tropical cyclone basins and almost entering a third.

From a climatological point of view, an occasional tropical cyclone may move into the Gulf of Thailand from the South China Sea, but it is rare for genesis and intensification to occur in the Gulf — a relatively small body of water surrounded by land on three sides. However, on the first of November, satellite imagery detected the presence of a concentrated area of convection with a well-organized upper-level anticyclone. At the same time, sparse ship reports in the Gulf showed that sea-level pressures were relatively high — near 1008 mb. The continued increase in the amount and organization of convection prompted JTWC to mention it on the 010600Z Significant Tropical Weather Advisory, noting that a low-level circulation was evident in the monsoon trough. Maximum sustained surface winds were estimated to be 10 to 15 kt (5 to 8 m/sec). During the next 15 hours, the disturbance continued to consolidate and estimated winds increased to 25 kt (13 m/sec). At 012100Z, JTWC issued a Tropical Cyclone Formation Alert.

Aided by its small size, dual outflow channels to the north and south, and the warm Gulf waters, the tropical cyclone spun up rapidly, and at 020000Z JTWC issued a 36-hour Tropical Depression Warning on Tropical Depression 32W. It became apparent that the cyclone would continue intensification, and six hours later, JTWC issued the first 72-hour Tropical Cyclone Warning on the system, upgrading it to tropical storm intensity. As Gay intensified, it presented a paradox to forecasters. While the satellite intensity estimates correctly diagnosed intensification, the synoptic data in Malaysia and Thailand indicated weakening winds and higher pressures. The synoptic data were correctly interpreted as indicators of increased subsidence produced by the intensifying midget system. Subsequent JTWC warnings thus reflected that Gay would reach typhoon intensity.

At 021800Z, Gay began to intensify more rapidly than anticipated reaching typhoon intensity at 030000Z. The eye apparently passed directly over the **Seacrest**, a commercial oil drilling ship moored in the Gulf. Confused seas with estimated heights of 35 to 45 feet (11 to 14 m) caused the ship to capsize shortly after eye passage. Gay's intensification continued, reaching 100 kt (51 m/s) at 040600Z just before it crashed into Champhun, Thailand which is located 210 nm (390 km) south-southwest of Bangkok. The radar at Champhun (WMO 48517) had tracked Gay for 18 hours, before its reports abruptly ceased shortly before the

typhoon (Figure 3-32-1) came inshore. At least four hundred and fifty-eight people were died and over 600 fishermen were reported missing at sea. In addition, two hundred fishing vessels were lost or missing.

As Gay moved slowly to the northwest in the Gulf, JTWC forecasters anticipated that a ridge would build to the north, and correctly forecast the cyclone to make a left turn and move across the Malay Peninsula. Gay weakened briefly as it crossed the Peninsula, entering the Bay of Bengal with maximum winds of 65 kt (33 m/s) at 041200Z. Situated south of the mid-level ridge, Gay continued to track west-northwestward across the Bay of Bengal at an average speed of 10 kt (19 km/hr). Gay intensified slowly in an area of weak vertical wind shear and warm sea surface temperatures, reaching an intensity of 95 kt (49 m/sec) by 051200Z. Restrictions to the upper-level outflow inhibited further development for the next 36 hours.

At 070000Z, Gay attained an intensity of 100 kt (51 m/sec), and took a more westward course as the mid-level ridge strengthened to the north. Without any significant restrictions to its outflow, the cyclone intensified for the next 42 hours until it reached the coast of India. Gay (Figure 3-32-2) reached super typhoon intensity at 080600Z, with winds of 130 kt (67 m/sec). Gay (Figure 3-32-3) made landfall in a sparsely populated area of India approximately 120 nm

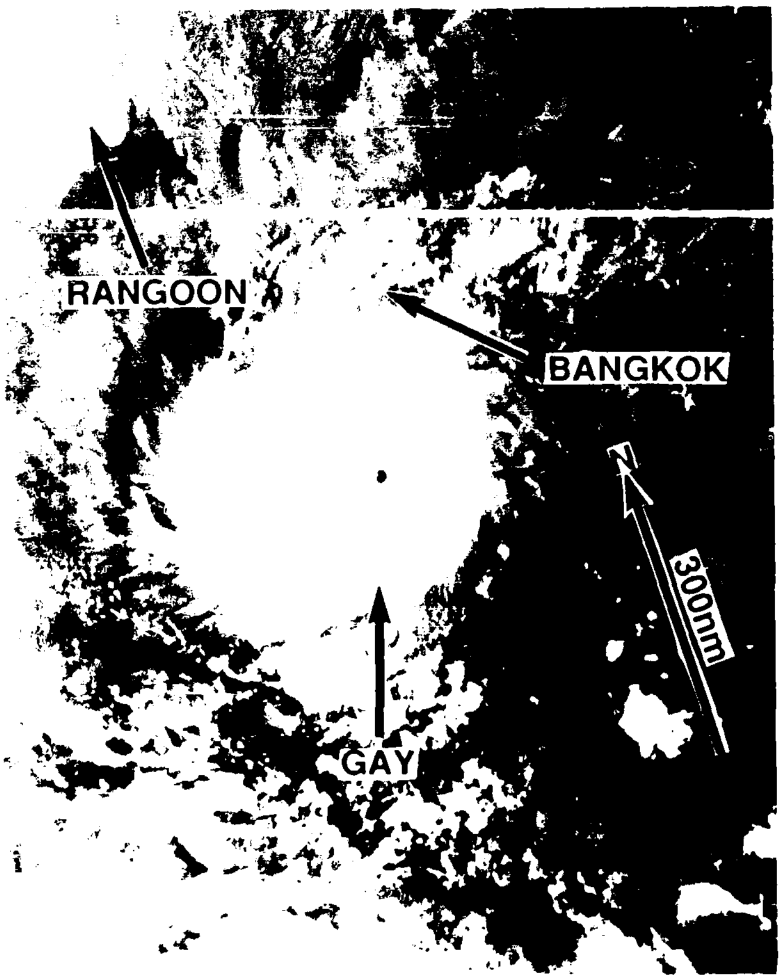

Figure 3-32-1. Typhoon Gay as it makes landfall on the Malay Peninsula. More than 1000 people were reported dead or missing in Gay's aftermath (040042Z November NOAA visual imagery).

(220 km) north of Madras at 081800Z, with maximum sustained winds estimated at 140 kt (72 m/sec). While there was concern that the Dvorak intensity estimation technique might have overestimated Gay's intensity, photos of destruction showed that Gay was a very intense, but very small, cyclone. In-country analyses of Indian synoptic data indicated that the 30-kt (15-m/sec) wind radii did not extend much beyond 50 nm (95 km) — (personal communication with Dr. G. S. Mandal, Indian Meteorological Service).

Twelve hours after making landfall, Gay had weakened to 45 kt (23 m/s). Because of the possibility of its reemergence into the Arabian Sea, JTWC continued to issue warnings on the system as it moved across India at 13 kt (24 km/hr). After 090600Z, Gay took a more northwestward overland track. At 100600Z, JTWC issued its final warning as the system dissipated in the Western Ghats approximately 75 nm (140 km) southeast of Bombay. Gay weakened much faster than anticipated as it moved across India. This was a result of its small size and small over-water fetch. Once inland the small fetch, which supplied Gay's latent heat source, was rapidly cut off. Because Gay was so small and went inshore in a rural area, it caused only 39 deaths. However, over 20,000 homes were destroyed or damaged.

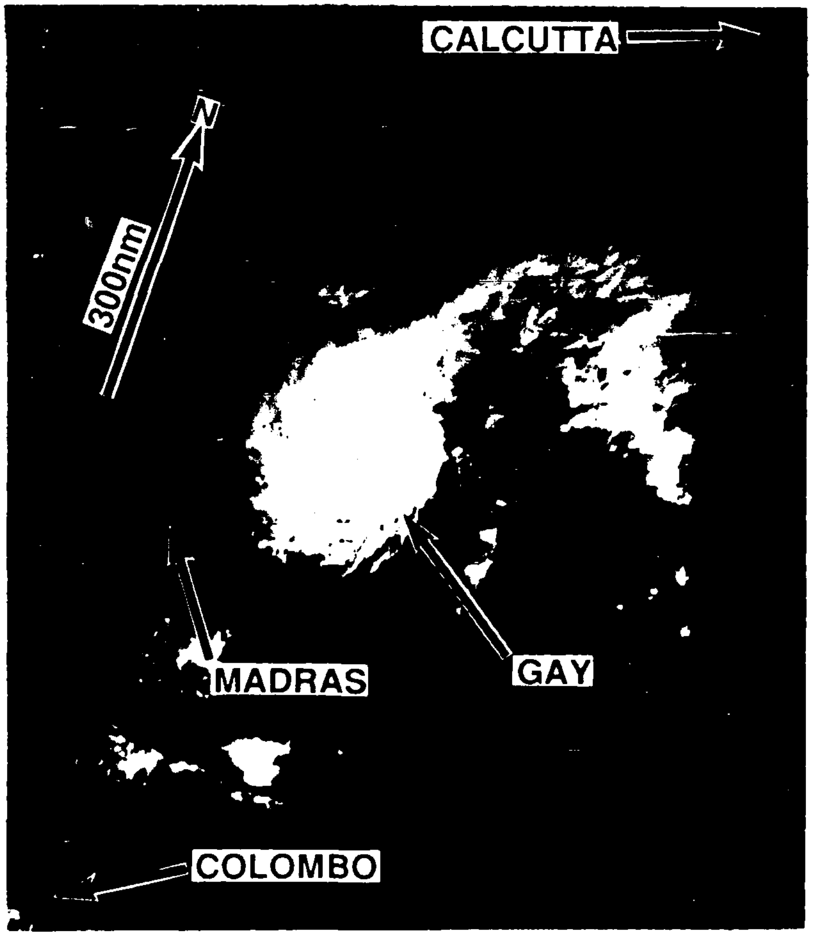

Figure 3-32-2. Gay approaches super typhoon intensity. The small eye appears in a small, compact central dense overcast (080340Z November DMSP visual imagery).

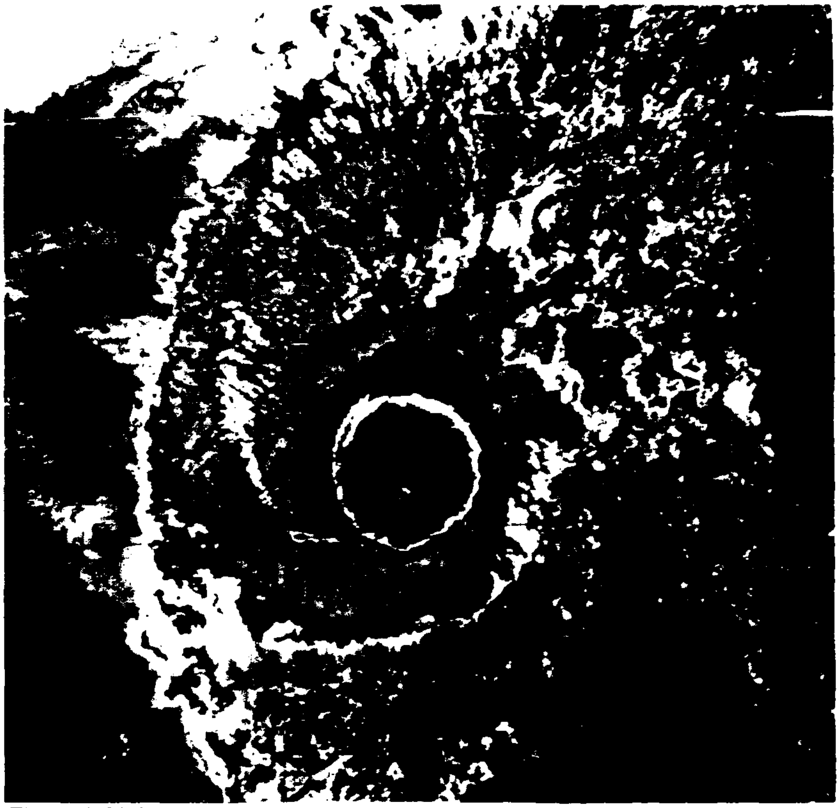

Figure 3-32-3. Enhanced infrared (above) and low-light visual (below) satellite picture pair of Gay at the coast of India. The city lights, the moonlit coast line and Gay's cloudiness show on the visual image. The enhanced infrared reveals the small eye and cold surrounding overcast (081612Z November DMSP visual and infrared imagery).

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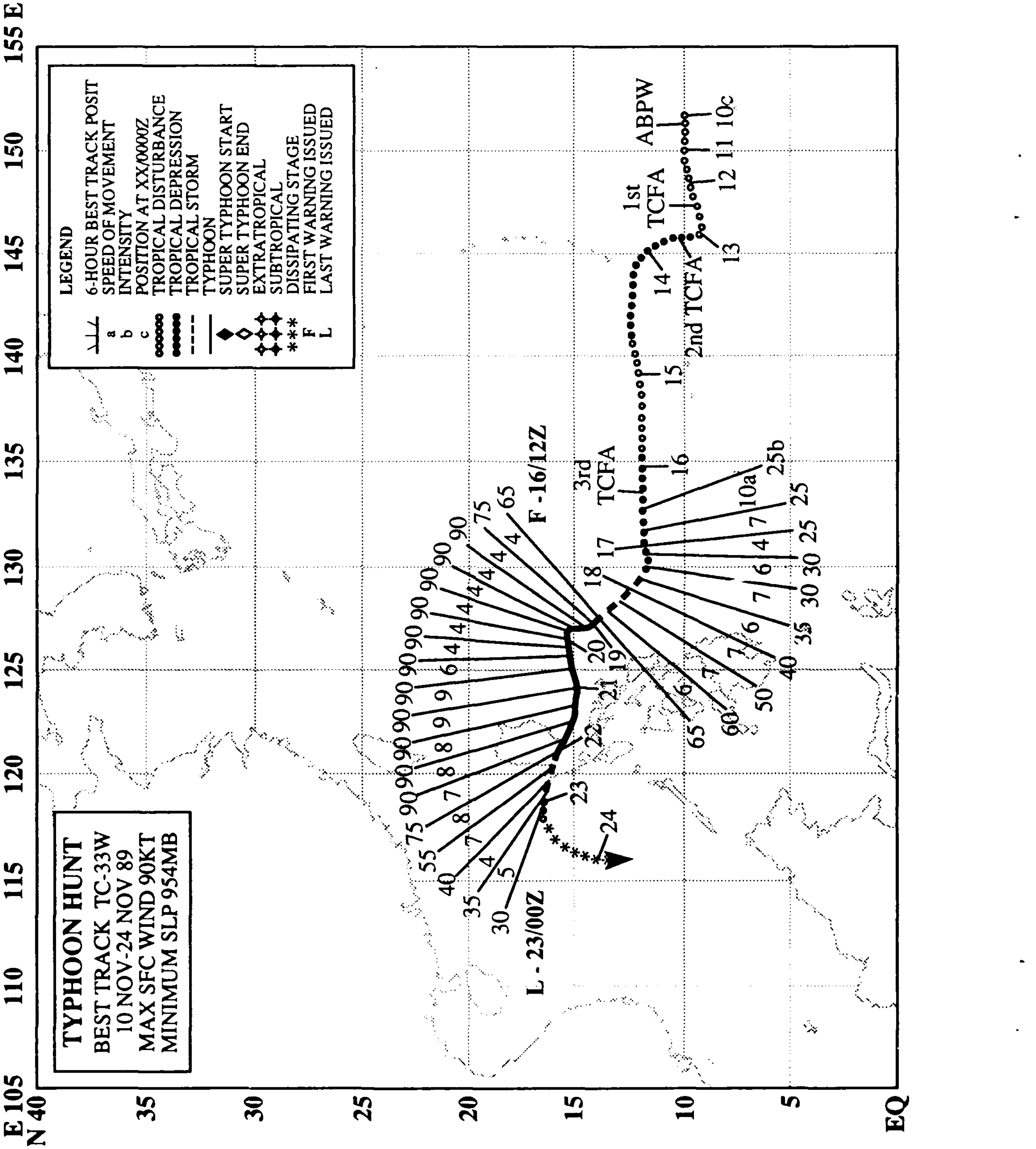

TYPHOON HUNT
BEST TRACK TC-33W
10 NOV-24 NOV 89
MAX SFC WIND 90KT
MINIMUM SLP 954MB
LEGEND
6-HOUR BEST TRACK POSIT
SPEED OF MOVEMENT
INTENSITY
POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
F - 16/12Z
L - 23/00Z
ABPW
1st TCFA
2nd TCFA
3rd TCFA
E 105
155 E
N 40
EQ

TYPHOON HUNT (33W)

Typhoon Hunt was the fourth typhoon, following Angela (26W), Dan (29W) and Elsie (30W), to strike the Philippine Islands within six weeks. Generally a westward moving system, it was slow to develop, but finally intensified rapidly in the western Philippine Sea. As it intensified and approached the Philippines, it underwent a northwestward "stair step" before resuming a westward course into central Luzon. Unlike Angela (26W), Dan (29W) and Elsie (30W) which reintensified after crossing Luzon, Hunt weakened dramatically and dissipated in the South China Sea.

Except for Typhoon Gay (32W), early November was relatively inactive in the western North Pacific. The cloud cluster that became Typhoon Hunt was first identified on the 10 November Significant Tropical Weather Advisory. This system was a weak tropical disturbance embedded in the monsoon trough north of the island of Truk in the central Caroline Islands. The cloud cluster remained poorly defined and drifted slowly westward for two days. After synoptic data indicated falling surface pressures, JTWC issued a Tropical Cyclone Formation Alert at 121000Z. The disturbance was located 270 nm (500 km) southeast of Guam. As the passage of a mid-latitude trough to the northeast of Guam weakened the mid-level subtropical ridge. On 13 November, the disturbance executed an abrupt track change to the north towards Guam. The Alert was reissued at 131000Z, approximately 220 nm (405 km) south-southeast of Guam.

The system moved northward for a day, then turned sharply westward, passing 90 nm (165 km) south of Guam. Increasing vertical shear weakened the convection significantly, and the Alert was canceled at 140400Z. On 16 November, the organization of the disturbance improved, as southwesterly winds of 20 to 30 kt (10 to 15 m/sec) were reported by ships and land stations. JTWC issued its third Alert on the system at 160730Z.

Continued organization led to the first warning on Tropical Depression 33W at 161200Z. In response to a mid-latitude trough passage to the north, the depression appeared to slow and then dip southward for six hours. As the trough moved out to the northeast, the 500 mb ridge remained very narrow but split into two cells, one to the northwest of the tropical cyclone and another to the northeast. A broad col area remained north of the tropical depression which then moved northwestward towards this weakness.

At 180000Z, the depression was upgraded to Tropical Storm Hunt with maximum sustained winds of 35 kt (18 m/sec). Hunt intensified rapidly while moving northwestward and was upgraded to a typhoon at 181800Z. JTWC continued to forecast movement over Luzon and predict the system would enter the South China Sea just south of Manila Bay. This was based on NOGAPS prognostic fields which indicated that the narrow 500 mb ridge would reestablish and maintain itself to the north of the system, thus forcing a westward track. At the same time, a strong 850 mb ridge of continental polar air associated with the winter monsoon extended eastward from southern China. This was also expected to block Hunt's northward progression. However, the NOGAPS forecast series proved to be too fast at reestablishing the ridge and Hunt turned northward toward the weakness in the ridge.

At this time, the typhoon also slowed to 4 kt (7 km/hr). Now JTWC and U.S. forces from the Philippines to Okinawa faced the dilemma of having a destructive system either affect forces in the Philippines should Hunt make only a "stair step," or in Okinawa, should it recurve. Because weak mid-latitude troughs, embedded in the predominantly zonal flow, continued to pass north of the tropical cyclone, and the prognostic series continued to build the

narrow 500 mb ridge as a barrier to Hunt's continued northward movement, JTWC persisted with its forecast of westward movement.

At 091500Z Typhoon Hunt, with its 90-kt (46-m/sec) maximum sustained winds, turned sharply to the west toward central Luzon as the 500 mb ridge to the system's northeast built westward and strengthened. Hunt remarkably maintained its 90-kt (46-m/sec) intensity for 66 continuous hours before moving ashore in central Luzon at 212000Z (Figure 3-33-1). Army personnel involved in the joint-combined U.S.-Philippine exercise, BALIKATAN 89, were deployed to Fort Magsaysay near Clark AB. The Weather Support Force for the exercise reported peak winds of 52 kt (27 m/sec) at 212200Z when Hunt was 40 nm (75 km) northeast of its location. As the typhoon crossed Luzon, it killed at least seven Filipino people. Damage to military installations was slight.

Hunt was downgraded to a tropical storm at 220600Z as it entered the Lingayen Gulf. The northeast monsoon was of moderate strength in the South China Sea, and Hunt, despite moving over warm water, continued to weaken due to strong vertical wind shear. Deep convection had completely subsided by 230000Z when Hunt was downgraded to a tropical depression and the final warning was issued. The remains of the low-level circulation, although not visible on satellite imagery, were last discernible on synoptic charts at 240000Z drifting southward in the monsoonal flow.

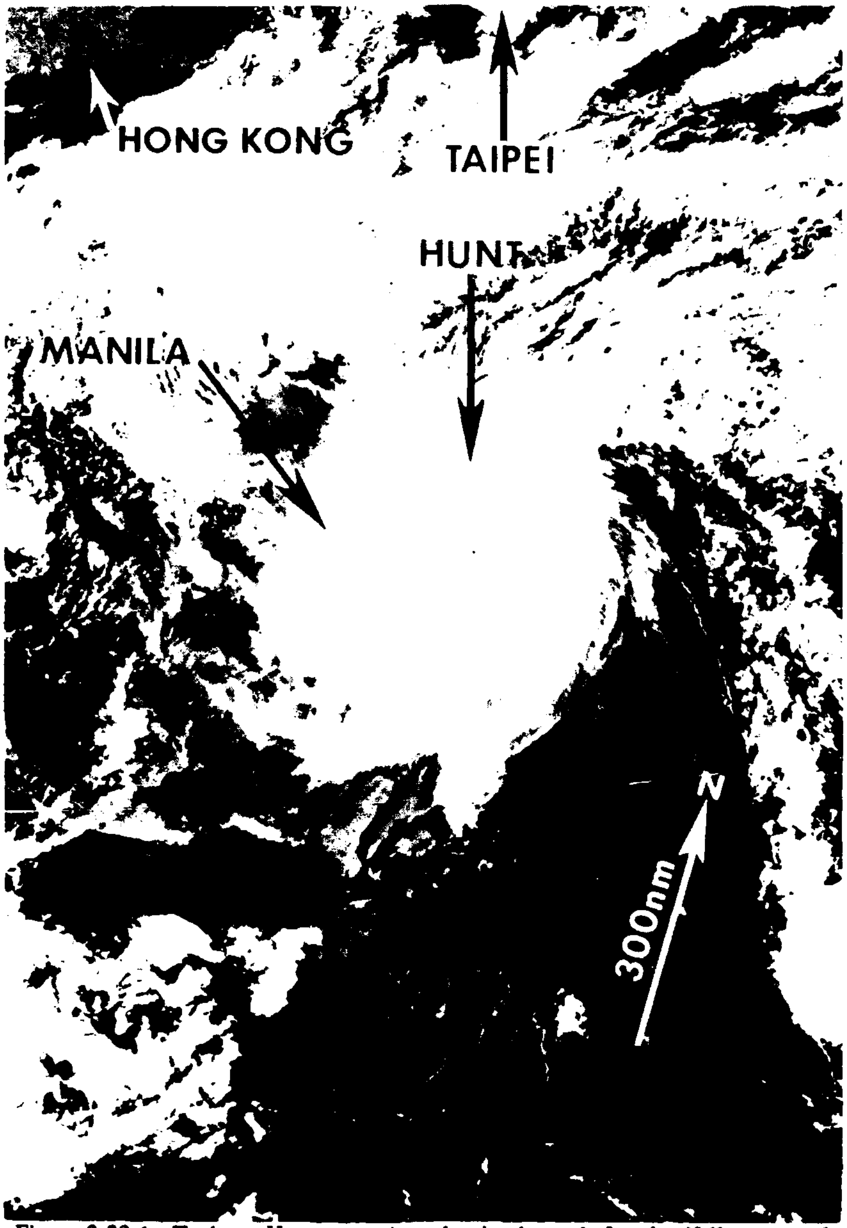
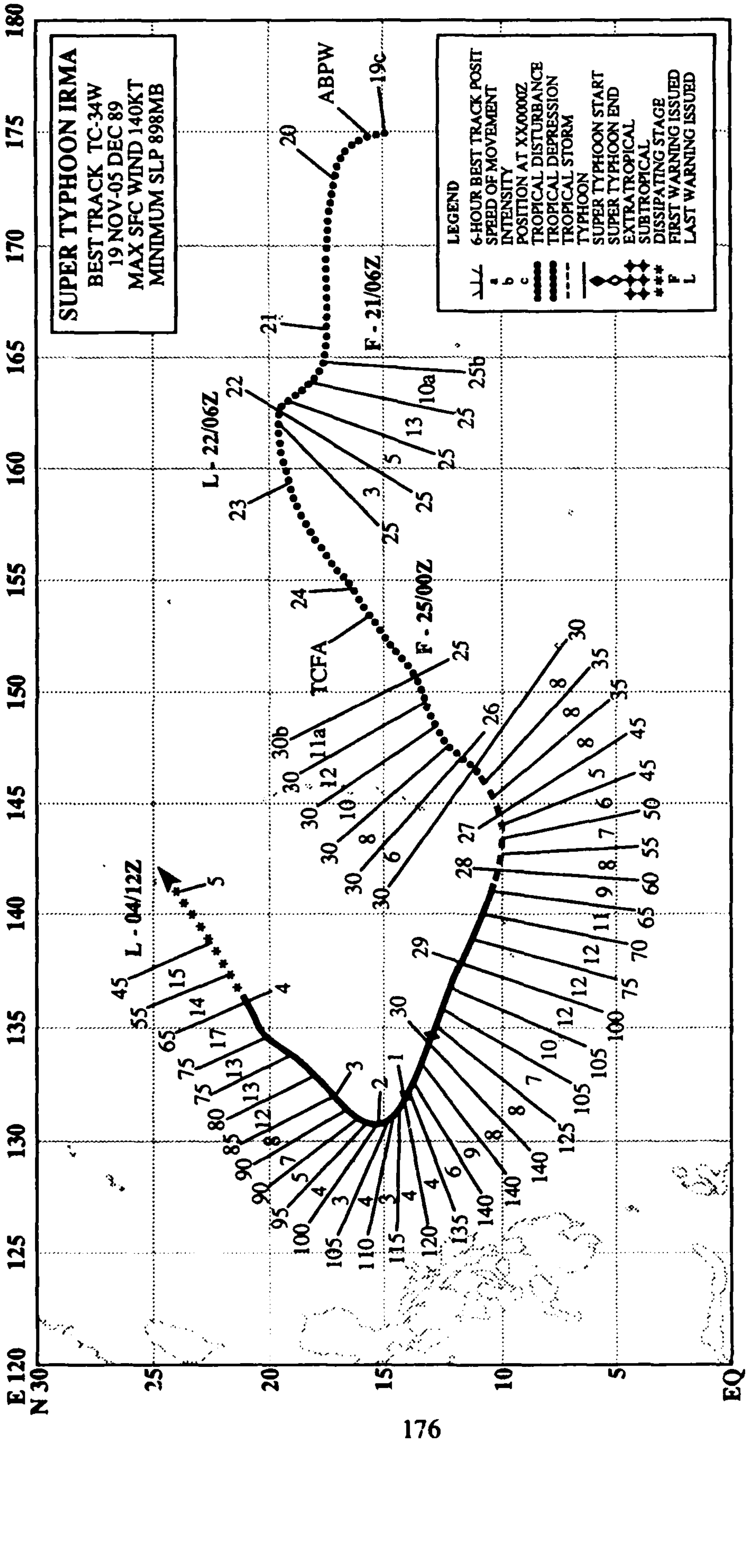


Figure 3-33-1. Typhoon Hunt approximately nine hours before landfall on central Luzon. Maximum sustained winds are estimated at 90 kt (46 m/sec) (211130Z November DMSP visual imagery).


SUPER TYPHOON IRMA
BEST TRACK TC-34W
19 NOV-05 DEC 89
MAX SFC WIND 140KT
MINIMUM SLP 898MB
LEGEND
6-HOUR BEST TRACK POSIT
SPEED OF MOVEMENT
INTENSITY
POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
ABPW
TCFA
F - 21/06Z
L - 22/06Z
F - 25/00Z
L - 04/12Z

SUPER TYPHOON IRMA (34W)

Irma was the third and final tropical cyclone to form in November. It's development and track were dictated by complex mid-latitude and monsoonal regimes. Initially, Irma was slow to develop, however, rapid intensification followed once it was in the Philippine Sea. Irma lasted 17 days and required a total of 39 warnings -- only Super Typhoon Angela (26W) exceeded this longevity with a total of 46 warnings.

In the middle of November, disturbed weather associated with a TUTT low developed 580 nm (1075 km) northeast of Kwajalein Atoll in the Marshall Islands. The disturbance was first mentioned on the Significant Tropical Weather Advisory at 182300Z. Because of significant vertical wind shear affecting the system, JTWC opted for a 36-hour Tropical Depression Warning at 210600Z instead of a 72-hour Tropical Cyclone Warning. Increasing upper-level flow around the TUTT low led to increasing shear above the depression, and a final Tropical Depression Warning followed at 220600Z. However, JTWC continued to mention the poorly defined remnants each day on the Significant Tropical Weather Advisory.

From 22 to 27 November, the system moved a record-breaking five days to the southwest, traveling from 20° to 10° north latitude. During this period from 22 to 24 November, the system tracked southwestward along the edge of a shear zone and continued to exhibit partially tropical characteristics. Eventually the southwestward track carried the system into an area of less vertical wind shear, where a flare up in convective activity led to a

Figure 3-34-1. An extensive field of closed cell stratocumulus appear to the north through west of Super Typhoon Irma (300431Z November NOAA visual imagery).

Tropical Cyclone Formation Alert at 240600Z. This development continued and at 250000Z a Tropical Depression Warning was issued. As the polar air mass along the shear line became well-modified in the tropics and anticyclonic outflow became more symmetric aloft, conditions improved for development. At 261200Z, JTWC issued the first Tropical Cyclone Warning on Tropical Depression 34W.

As the track became more westerly at 261800Z, Tropical Depression 34W was upgraded to Tropical Storm Irma. As a mid-latitude short wave trough approached from the northwest, enhancing Irma's outflow, rapid intensification occurred and JTWC upgraded the tropical cyclone to a typhoon at 280600Z. As a second short wave approached, Irma (Figure 3-34-1) attained super typhoon intensity at 300000Z. This increase in intensity was short lived, however. With the passage to the east of the shortwave also came stronger westerly winds aloft and an accompanying surge in the low-level northeast monsoon. These factors, plus the entrainment of cold air, weakened Irma (Figure 3-34-2) below super typhoon intensity at 010000Z.

Since 27 November the track to the west-northwest brought Irma closer to the polar westerlies aloft. Irma's forward motion slowed gradually as the cyclone approached the western

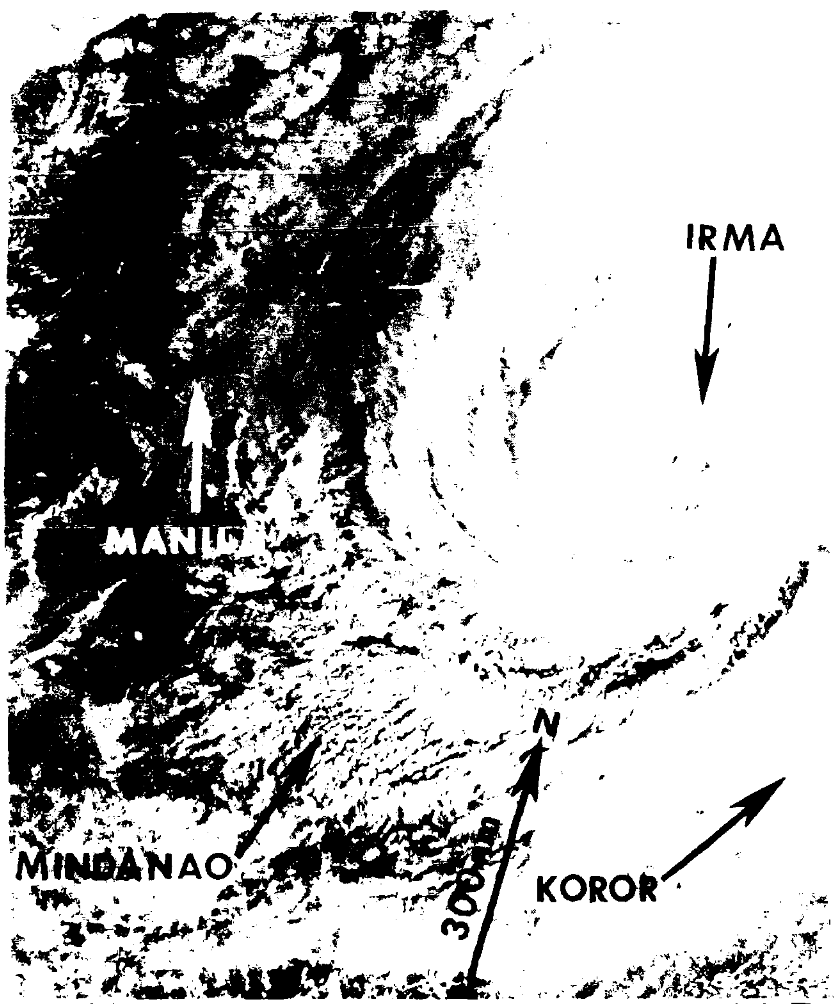
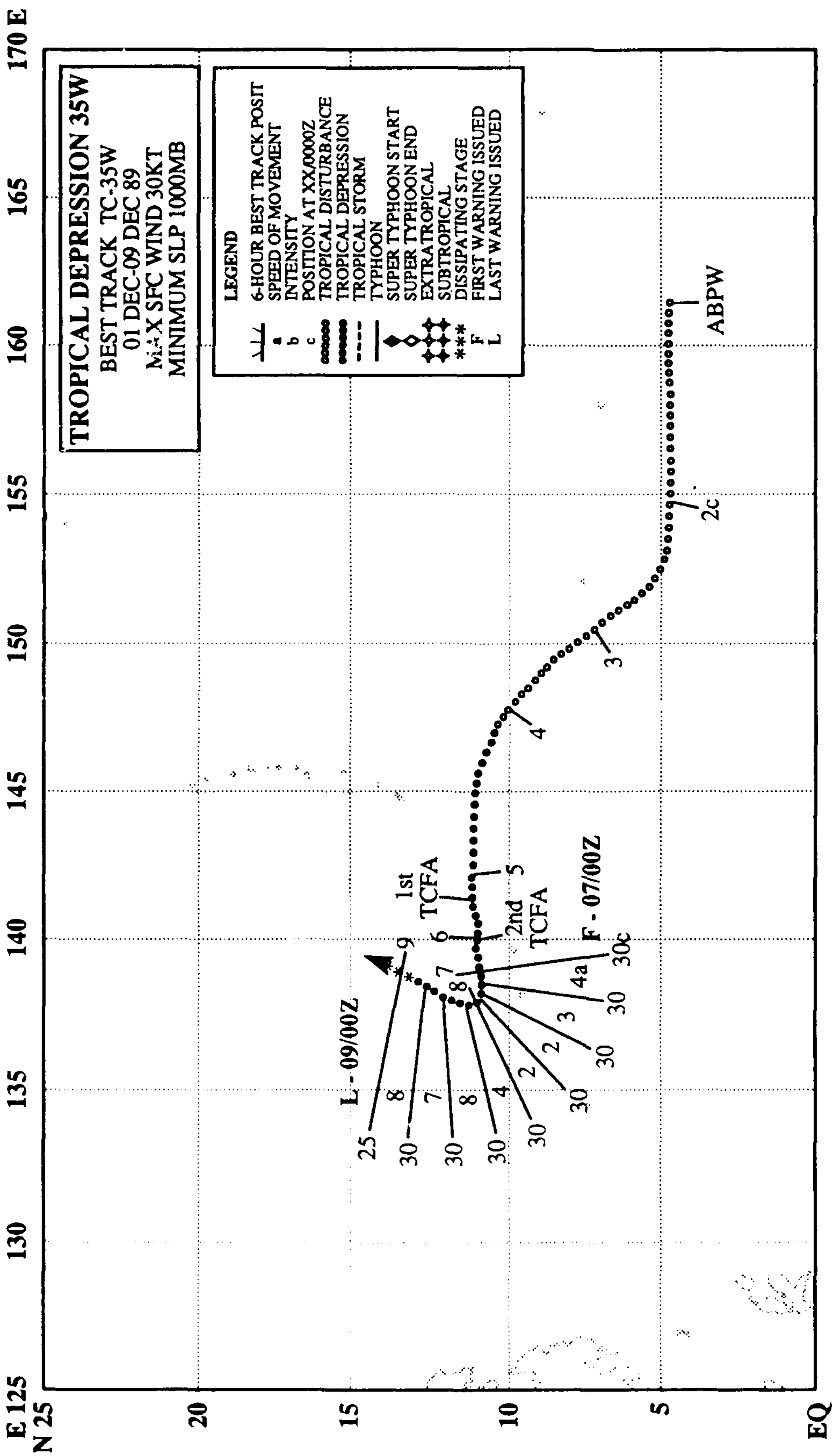


Figure 3-34-2. Irma's central dense overcast is elongated and asymmetrical. The eye is filling with clouds and the super typhoon is weakening (302151Z November DMSP visual imagery).

periphery of the subtropical ridge. The entire fall of 1989 had be characterized by zonal westerly mid-tropospheric flow and a very narrow subtropical ridge in the extreme western Pacific. Because of the 250 nm (465 km) wide ridge, even straight moving cyclones were very close to becoming recurvature ones. JTWC expected the flow to remain zonal, and for Irma to resume westward movement into the Philippine Islands. However, on 2 December, another short wave moved eastward from the coast of Asia. This trough deepening further equatorward than the previous short waves and Irma recurved 630 nm (1165 km) east of Manila. The typhoon accelerated in response to the stronger westerly flow aloft and weakened in the strong shearing environment. The final warning was issued at 041200Z. The remnants of Irma were no longer visible on the satellite imagery on 5 December. JTWC received no reports of damage caused by Irma.



TROPICAL DEPRESSION 35W
BEST TRACK TC-35W
01 DEC-09 DEC 89
MAX SFC WIND 30KT
MINIMUM SLP 1000MB
LEGEND
6-HOUR BEST TRACK POSIT
SPEED OF MOVEMENT
INTENSITY
POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
ABPW
1st TCFA
2nd TCFA
F - 07/00Z
L - 09/00Z
E 125
130
135
140
145
150
155
160
165
170 E
N 25
20
15
10
5
EQ

TROPICAL DEPRESSION 35W

Detected on the first day of December, Tropical Depression 35W lasted more than a week as a discrete system, although it was in warning status only 48 hours.

As Super Typhoon Irma (34W) was weakening in the Philippine Sea, a weak surface circulation and an associated area of convection were detected in the western Marshall Islands. The tropical disturbance was mentioned on the 010600Z Significant Tropical Weather Advisory as a poor suspect area. Over the next five days this tropical disturbance moved generally west-northwestward and continued to organize very slowly. The presence of strong vertical wind shear arrested development and eventually weakened the system. After the disturbance passed to the south of Guam, the convection flared and at 050500Z the first Tropical Cyclone Formation Alert was issued. The Alert was reissued at 060500Z. Then, based on a satellite intensity estimate of 30-kt (15-m/sec) surface winds (Figure 3-35-1), a Tropical Cyclone Warning was issued at 070000Z. At 080000Z, the approach of a mid-level short wave trough from the northwest resulted in the depression abruptly changing track and recurving northeastward. Increased vertical wind shear from the west-southwest was responsible for further weakening the system. The final warning was issued at 090000Z as the cyclone dissipated over water.

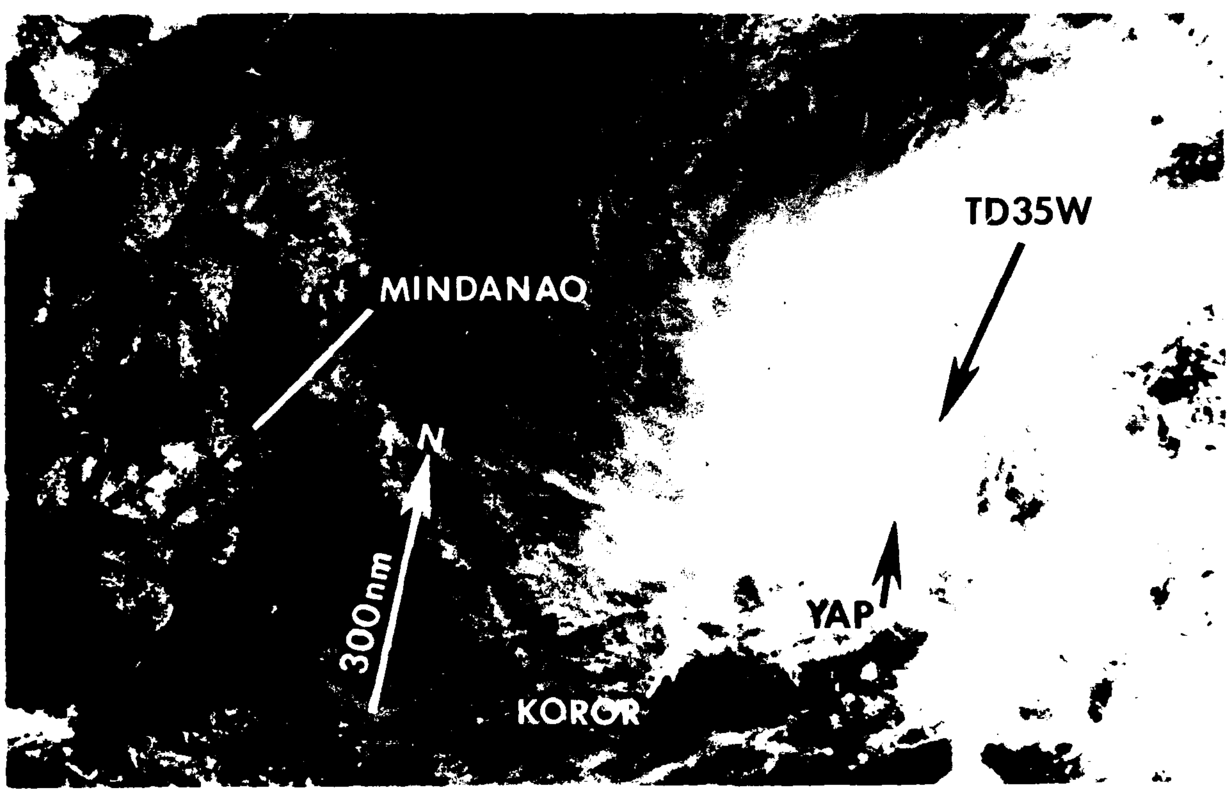
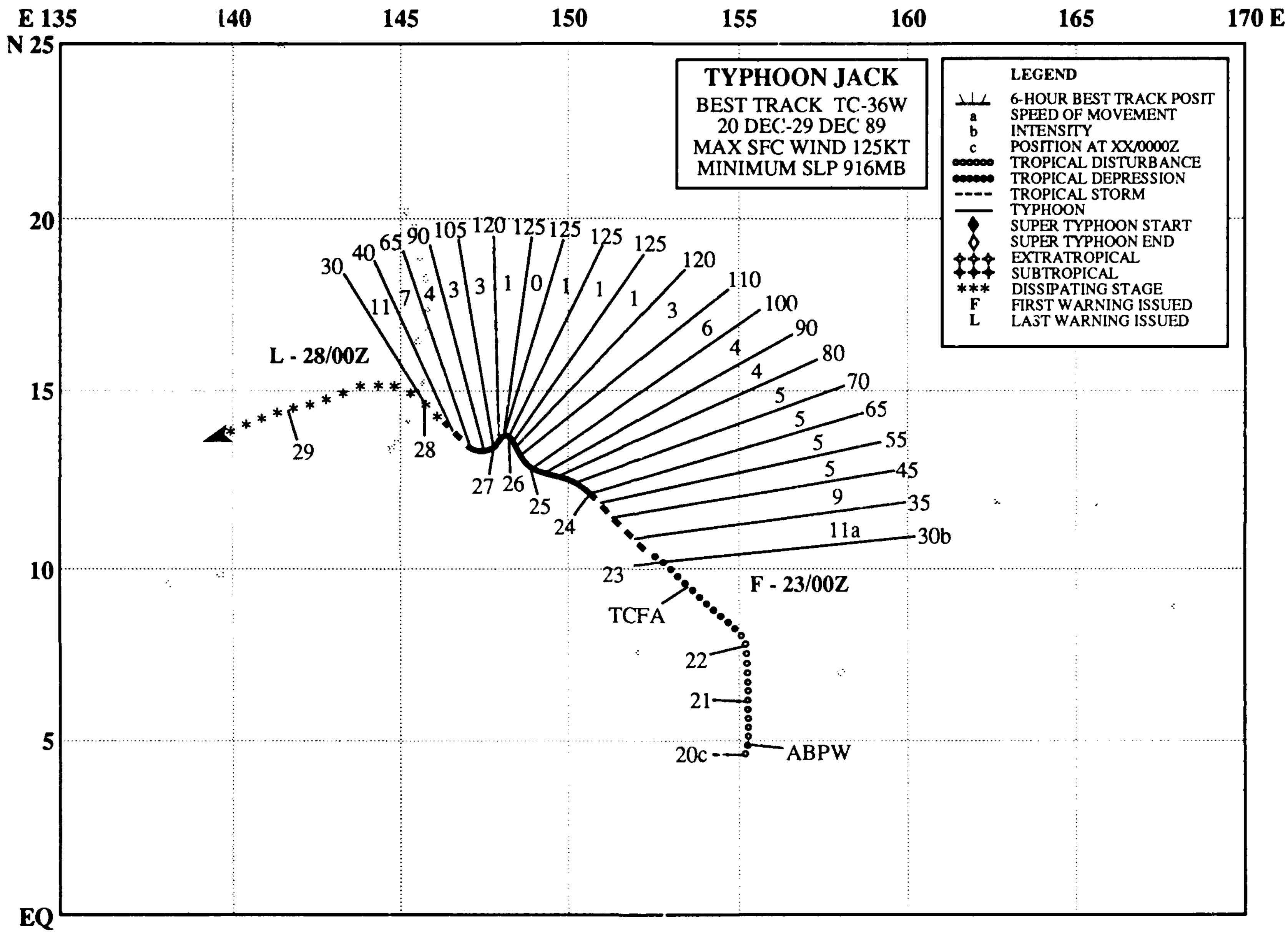


Figure 3-35-1. Tropical Depression 35W with 30-kt (15-m/sec) maximum sustained surface winds (070457Z December NOAA visual imagery).


TYPHOON JACK
BEST TRACK TC-36W
20 DEC-29 DEC 89
MAX SFC WIND 125KT
MINIMUM SLP 916MB
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 135
140
145
150
155
160
165
170 E
N 25
20
15
10
5
EQ
L - 28/00Z
F - 23/00Z
TCFA
ABPW
20c
21
22
23
24
25
26
27
28
29
30b
11a
35
9
45
5
55
5
65
5
70
5
80
4
90
4
100
6
110
3
120
1
125
1
125
1
125
0
125
1
120
3
105
3
90
4
65
7
40
11
30

TYPHOON JACK (36W)

The second tropical cyclone to form in December, Jack was the twenty-first typhoon and final tropical cyclone of the year. Typhoon Jack was noteworthy for the unusually long period it remained quasi-stationary and the extremely rapid dissipation that followed.

A broad area of poorly organized convection located approximately 240 nm (445 km) southeast of Truk was first noted on the 210600Z Significant Tropical Weather Advisory. The disturbed area of weather continued to organize slowly and a Tropical Cyclone Formation Alert was issued at 221900Z. At that time, the disturbance was 150 nm (275 km) northeast of Truk, moving west-northwestward at 8 kt (15 km/hr) with surface winds of 20 to 30 kt (10 to 15 m/sec). Over the next 8 hours, the upper-level anticyclonic circulation and the spiral bands of the disturbance increased significantly in organization, however, the low-level circulation remained weak. The combination of the rather tentative intensification of the disturbance and its movement in the general direction of Guam prompted the issuance of a Tropical Depression Warning at 230000Z. At that time Tropical Depression 36W was approximately 400 nm (740 km) southeast of Guam and forecast to move northwestward at 11 kt (20 km/hr).

The low-level organization of Tropical Depression 36W appeared to improve markedly on satellite imagery resulting in the issuance of a Tropical Cyclone Warning at 230600Z. The motion forecast for the next four days called for continued northwestward movement toward a weakness in the subtropical ridge near Guam, followed by recurvature due to an approaching short-wave trough. The system did reach a weak area at the axis of the subtropical ridge in about two days. However, the broad nature of the ridge blocked Jack's movement in all directions. This caused the cyclone to stall in a

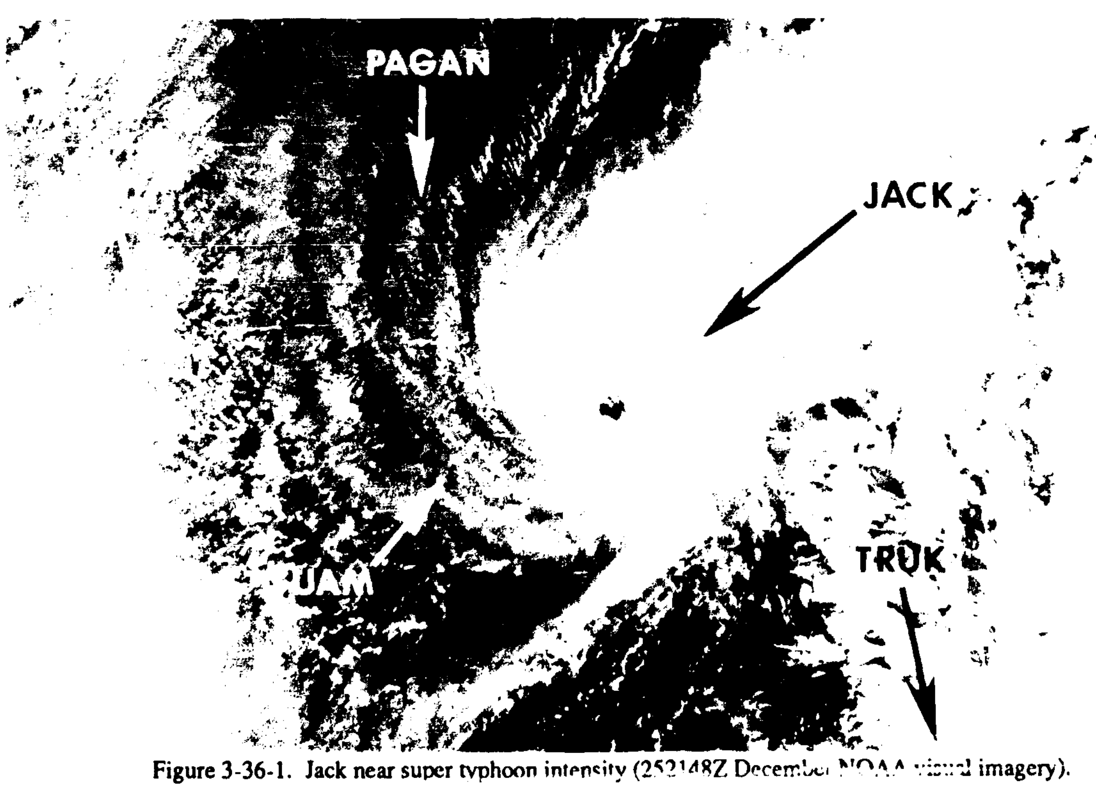


Figure 3-36-1. Jack near super typhoon intensity (252148Z December NOAA visual imagery).

large area of weak mid-level steering at a latitude too far south to permit the passing short-wave trough to initiate recur-vature. Jack had closed to within 185 nm (345 km) of Guam before stalling. The proximity to Guam allowed surveillance to be conducted by the weather radar at Andersen AFB (WMO 91218). In what is almost certainly a record for almost no motion, radar surveillance doc-umented that Jack moved only about 60 nm (110 km) from 250710Z to 270335Z, and moved less than 20 nm (35 km) from 251210Z to 261210Z. Jack's eye, with a diameter of 20 to 30 nm (37 km to 55 km), made an ideal target for remote sensing. The typhoon was essentially stationary in a non-shearing environment for nearly 48 hours.

Not surprisingly, the unusual motion of Typhoon Jack was accompanied by an equally unusual intensification and dissipation pattern. From a maximum wind speed of 30 kt (15 m/sec) at 222330Z, Jack rapidly deepened to a maximum wind speed of 115 kt (57 m/sec) at 250530Z, which corresponds to nearly two T-numbers per day using the Dvorak intensity estimation technique. It reached a peak intensity of 125 kt (67 m/sec; Dvorak T6.5) during the period 251800Z to 261200Z (Figure 3-36-1). Such an intensification pattern was unusual since Jack appeared to have only one well-defined outflow channel to the northeast. Normally, rapid deepening and the attainment of super-typhoon intensity are associated with the development of two efficient outflow channels.

As Jack began to show signs of prolonged quasi-stationary behavior, JTWC anticipated on the 260000Z warning that the upwelling of cold water at the cyclone's center, normally associated with the wind stress on the ocean's surface, might initiate a rapid weakening of the system due to its slow movement. Although

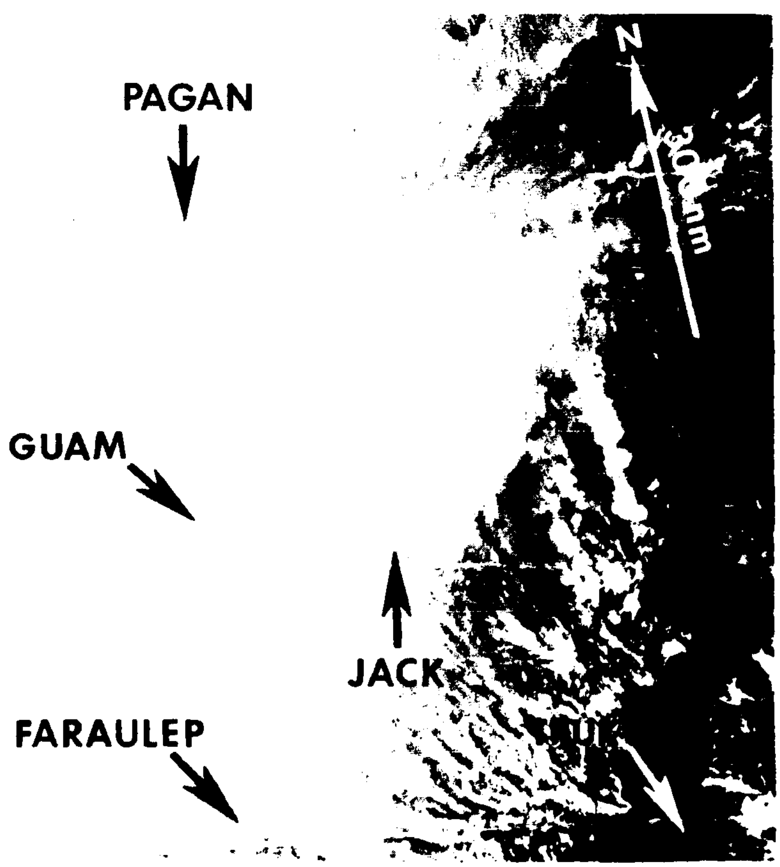


Figure 3-36-2. Jack as an intense typhoon only 24 hours before dissipation (262126Z December NOAA visual imagery).

such weakening did indeed occur, the extreme nature of the ensuing dissipation was surprising. At 270000Z, JTWC assessed the intensity of Jack (Figure 3-36-2) to be about 105 kt (54 m/sec). Figure 3-36-3 shows the remnants of Jack 24 hours later. All that remained was a 30-kt (15-m/sec) exposed low-level circulation located 120 nm (220 km) northeast of Guam. This remarkable weakening rate exceeded 15 kt (8 m/sec) per 6 hour forecast period. The remnants of the associated convective cloud mass were about 300 nm (555 km) to the south of the low-level circulation center. The vorticity associated with the cloud mass actually developed a secondary low-level circulation center that moved south of Guam on 28 December. Of interest, NOAA imagery on 29 December detected a cold water cyclonic eddy in the ocean where Jack had been quasi-stationary for nearly two days.

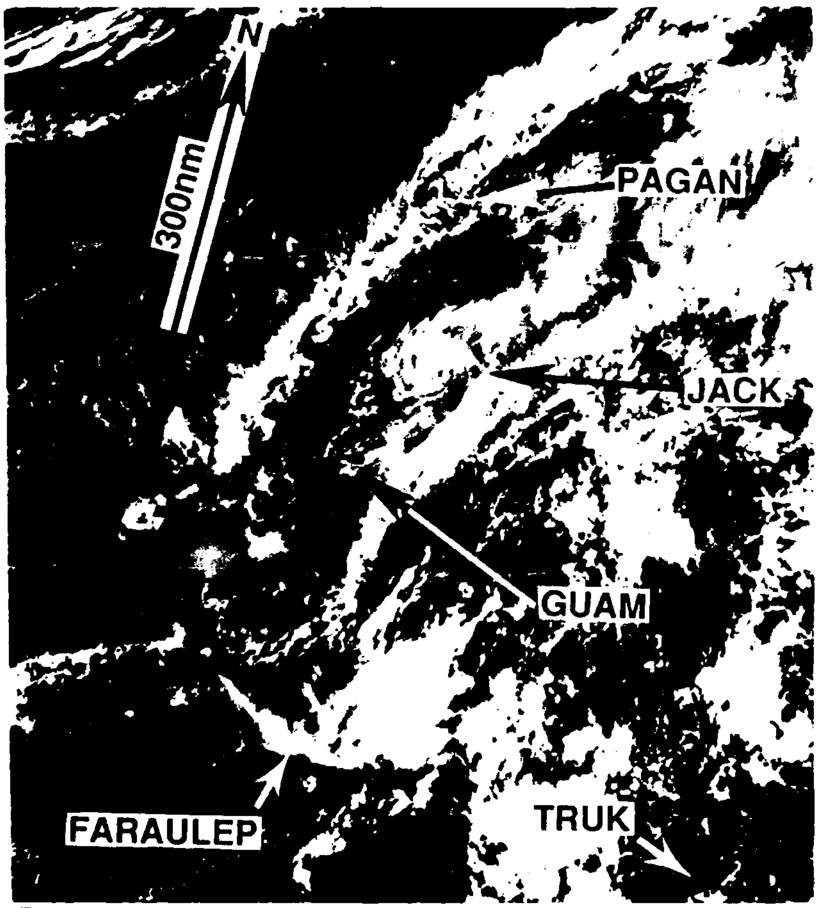


Figure 3-36-3. The remnants of Jack: an exposed low-level circulation center northeast of Guam, and the last vestige of the convection cloud mass to the south (272357Z December DMSP visual imagery)

3.3 NORTH INDIAN OCEAN TROPICAL CYCLONES

Spring and fall in the North Indian Ocean are periods of transition between major climatic controls and the most favorable seasons for tropical cyclone activity (Tables 3-5 and 3-6). Two significant tropical cyclones developed in the North Indian Ocean in the spring, however, no tropical cyclones developed in the fall transition season. The most interesting event was the passage of Tropical Cyclone 32W (Gay) into the Bay of Bengal from the Gulf of Thailand. It maintained typhoon intensity while crossing the Malay Peninsula and reached super typhoon intensity which is rare in the Bay of Bengal.

In summary, 1989 tropical cyclone activity was below the 1988 and 15-year average of five (Table 3-6).

TABLE 3-5. **1989 SIGNIFICANT TROPICAL CYCLONES NORTH INDIAN OCEAN**

TROPICAL CYCLONE	PERIOD OF WARNING	NUMBER OF WARNINGS ISSUED	MAXIMUM SURFACE WINDS-KT (M/SEC)	ESTIMATED MSLP (MB)
TC 01B	23 MAY - 26 MAY	14	55 (28)	984
TC 02A	12 JUN - 13 JUN	5	35 (18)	996*
TC 32W	04 NOV - 10 NOV	25	140 (72)	898
	TOTAL:	44		

* BASED ON SYNOPTIC DATA

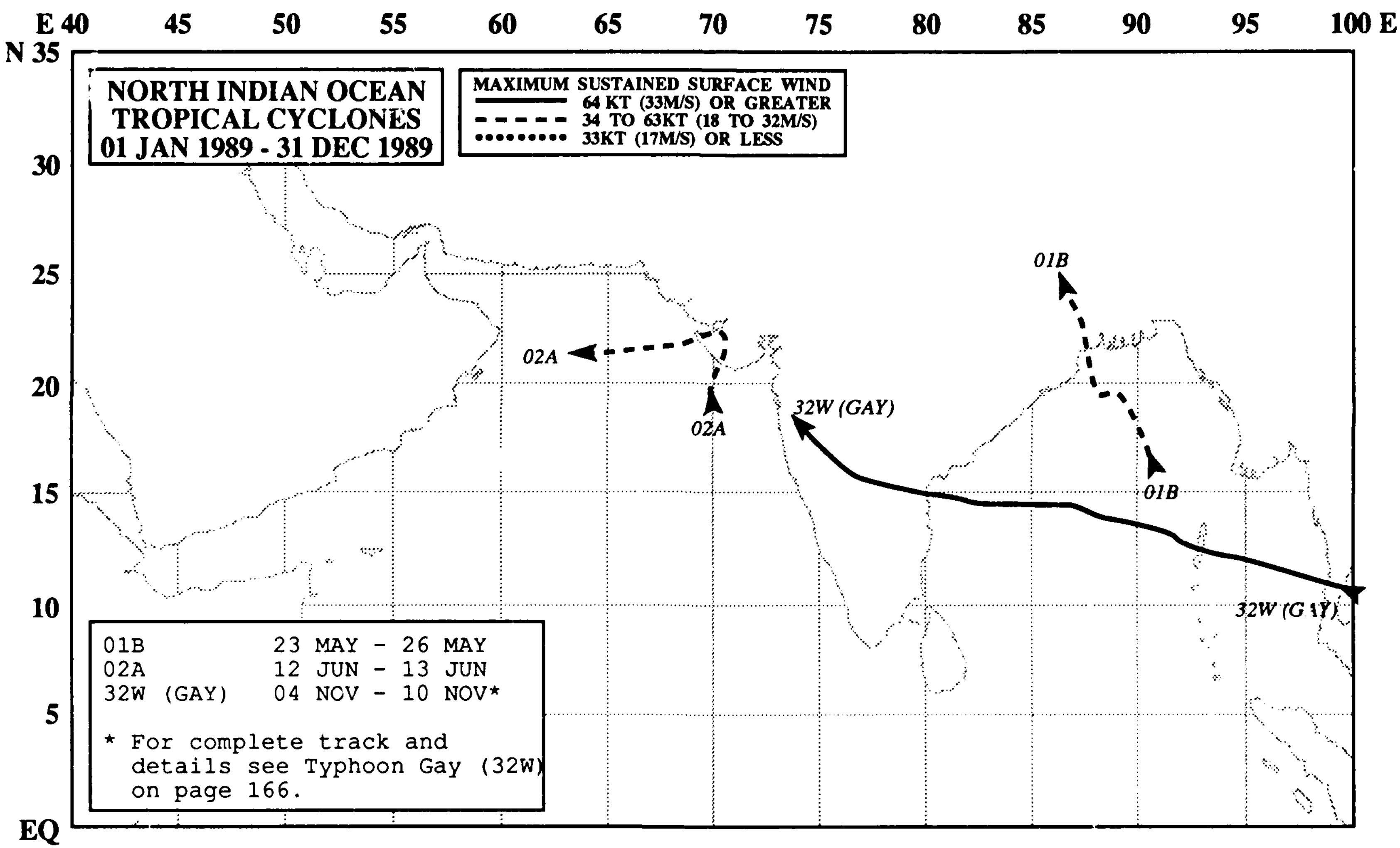
TABLE 3-6. **NORTH INDIAN OCEAN TROPICAL CYCLONES DISTRIBUTION**

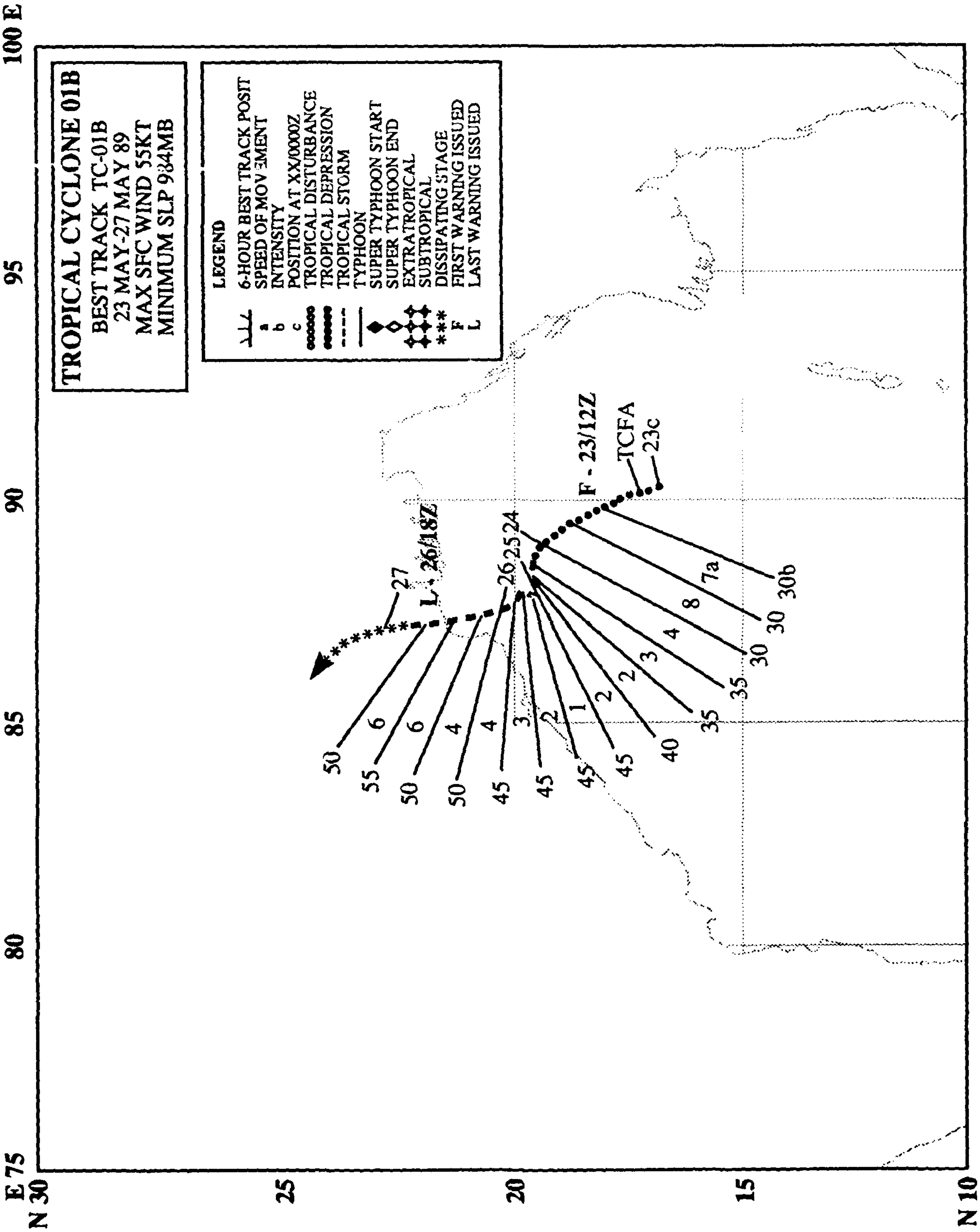
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1971*	-	-	-	-	-	0	0	0	0	1	1	0	2
1972*	0	0	0	1	0	0	0	0	2	0	1	0	4
1973*	0	0	0	0	0	0	0	0	0	1	2	1	4
1974*	0	0	0	0	0	0	0	0	0	0	1	0	1
1975	1	0	0	0	2	0	0	0	0	1	2	0	6
1976	0	0	0	1	0	1	0	0	1	1	0	1	5
1977	0	0	0	0	1	1	0	0	0	1	2	0	5
1978	0	0	0	0	1	0	0	0	0	1	2	0	4
1979	0	0	0	0	1	1	0	0	2	1	2	0	7
1980	0	0	0	0	0	0	0	0	0	0	1	1	2
1981	0	0	0	0	0	0	0	0	0	1	1	1	3
1982	0	0	0	0	1	1	0	0	0	2	1	0	5
1983	0	0	0	0	0	0	0	1	0	1	1	0	3
1984	0	0	0	0	1	0	0	0	0	1	2	0	4
1985	0	0	0	0	2	0	0	0	0	2	1	1	6
1986	1	0	0	0	0	0	0	0	0	0	2	0	3
1987	0	1	0	0	0	2	0	0	0	1	2	2	8
1988	0	0	0	0	0	1	0	0	0	1	2	1	5
1989**	0	0	0	0	1	1	0	0	0	0	1	0	3
(1975-1989)													
AVERAGE:	0.1	0.1	0.0	0.1	0.7	0.5	0.0	0.1	0.2	1.0	1.5	0.5	4.6
TOTAL:	2	1	0	1	10	8	0	1	3	14	22	7	69

* JTWC WARNING RESPONSIBILITY BEGAN ON 4 JUNE 1971 FOR THE BAY OF BENGAL, EAST OF 90° EAST LONGITUDE. AS DIRECTED BY CINCPAC, JTWC ISSUED WARNINGS ONLY FOR THOSE TROPICAL CYCLONES THAT DEVELOPED OR TRACKED THROUGH THAT PART OF THE BAY OF BENGAL. COMMENCING WITH THE 1975 TROPICAL CYCLONE SEASON, JTWC'S AREA OF RESPONSIBILITY WAS EXTENDED WESTWARD TO INCLUDE THE WESTERN PART OF THE BAY OF BENGAL AND THE ENTIRE ARABIAN SEA.

** JTWC ISSUED EIGHT TROPICAL CYCLONE FORMATION ALERTS. FORMATION ALERTS WERE ISSUED FOR ALL OF THE SIGNIFICANT TROPICAL CYCLONES THAT DEVELOPED IN 1989. TROPICAL CYCLONE 32W WAS IN WARNING STATUS WHEN IT ENTERED THE BAY OF BENGAL.

WARNINGS: NUMBER OF CALENDAR WARNING DAYS: 13
THERE WERE NO CALENDAR WARNING DAYS WITH TWO OR MORE TROPICAL CYCLONES.


NORTH INDIAN OCEAN
TROPICAL CYCLONES
01 JAN 1989 - 31 DEC 1989
MAXIMUM SUSTAINED SURFACE WIND
64 KT (33M/S) OR GREATER
34 TO 63KT (18 TO 32M/S)
33KT (17M/S) OR LESS
E 40
45
50
55
60
65
70
75
80
85
90
95
100 E
N 35
30
25
20
15
10
5
EQ
01B
02A
32W (GAY)
01B 23 MAY - 26 MAY
02A 12 JUN - 13 JUN
32W (GAY) 04 NOV - 10 NOV*
* For complete track and details see Typhoon Gay (32W) on page 166.


TROPICAL CYCLONE 01B
BEST TRACK TC-01B
23 MAY-27 MAY 89
MAX SFC WIND 55KT
MINIMUM SLP 984MB
LEGEND
6-HOUR BEST TRACK POSIT
SPEED OF MOVEMENT
INTENSITY
POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
F - 23/12Z
TCFA
L - 26/18Z
100 E
95
90
85
80
E 75
N 30
25
20
15
N 10

TROPICAL CYCLONE 01B

Tropical Cyclone 01B was the first of two cyclones to affect the Bay of Bengal and the only one to form in the Bay this year.

In mid-May, the monsoon trough was well-established throughout the Bay of Bengal between 8° to 10° north latitude with the heaviest convection persisting over the southwestern portion of the Bay. On 20 May, there was a broad area of poorly organized convection formed in the eastern half of the Bay and sparse synoptic data suggested a circulation center. But it wasn't until late on 22 May that the organization improved and convection increased dramatically. This development prompted JTWC to issue a Tropical Cyclone Formation Alert at 230330Z and the first warning followed at 231500Z. The basic track to the north-northwest was interrupted on 24 and 25 May when weak mid-level steering resulted in an erratic and very slow movement.

Even though the system's development was slowed by northeast winds aloft, Tropical Cyclone 01B (Figure 3-01B-1) did attain a intensity of 55 kt (28 m/sec) at 261200Z, just before making landfall. After landfall the cyclone passed 60 nm (110 km) west of Calcutta, which recorded 25 kt (13 m/sec) sustained surface winds and a minimum sea-level pressure of 988 mb. Then, the dissipating circulation tracked northward into the heat low . No reports of damage were received.

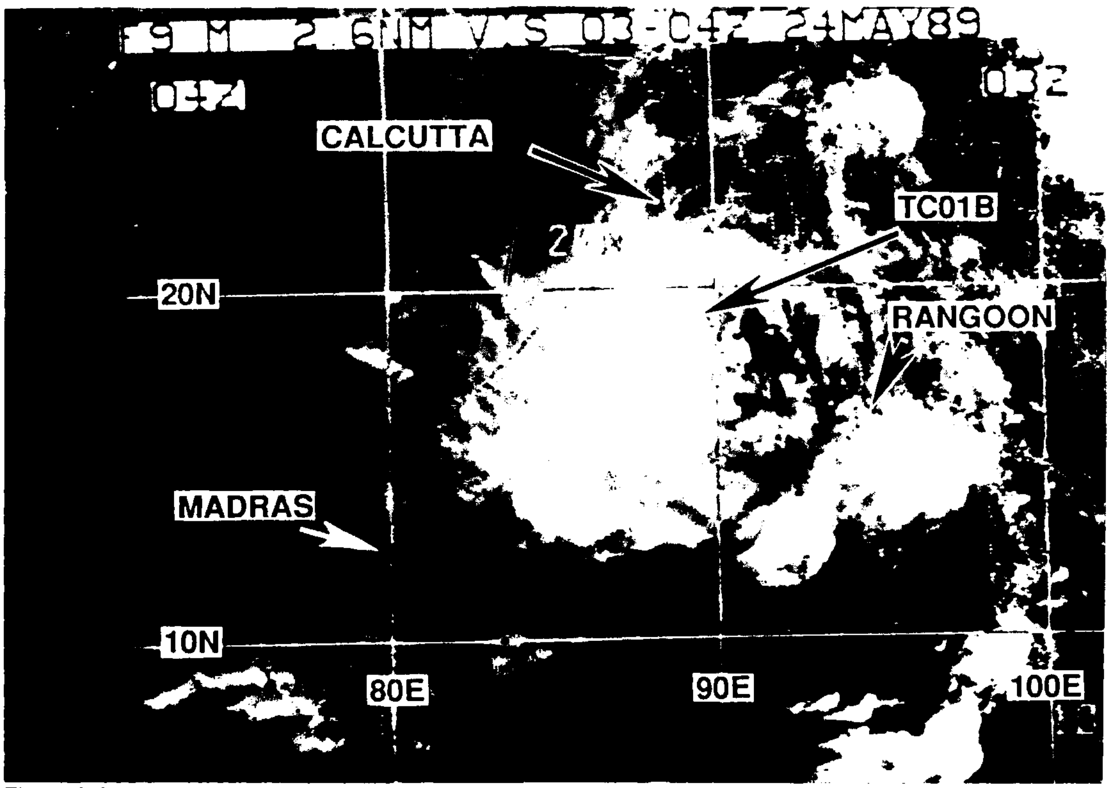
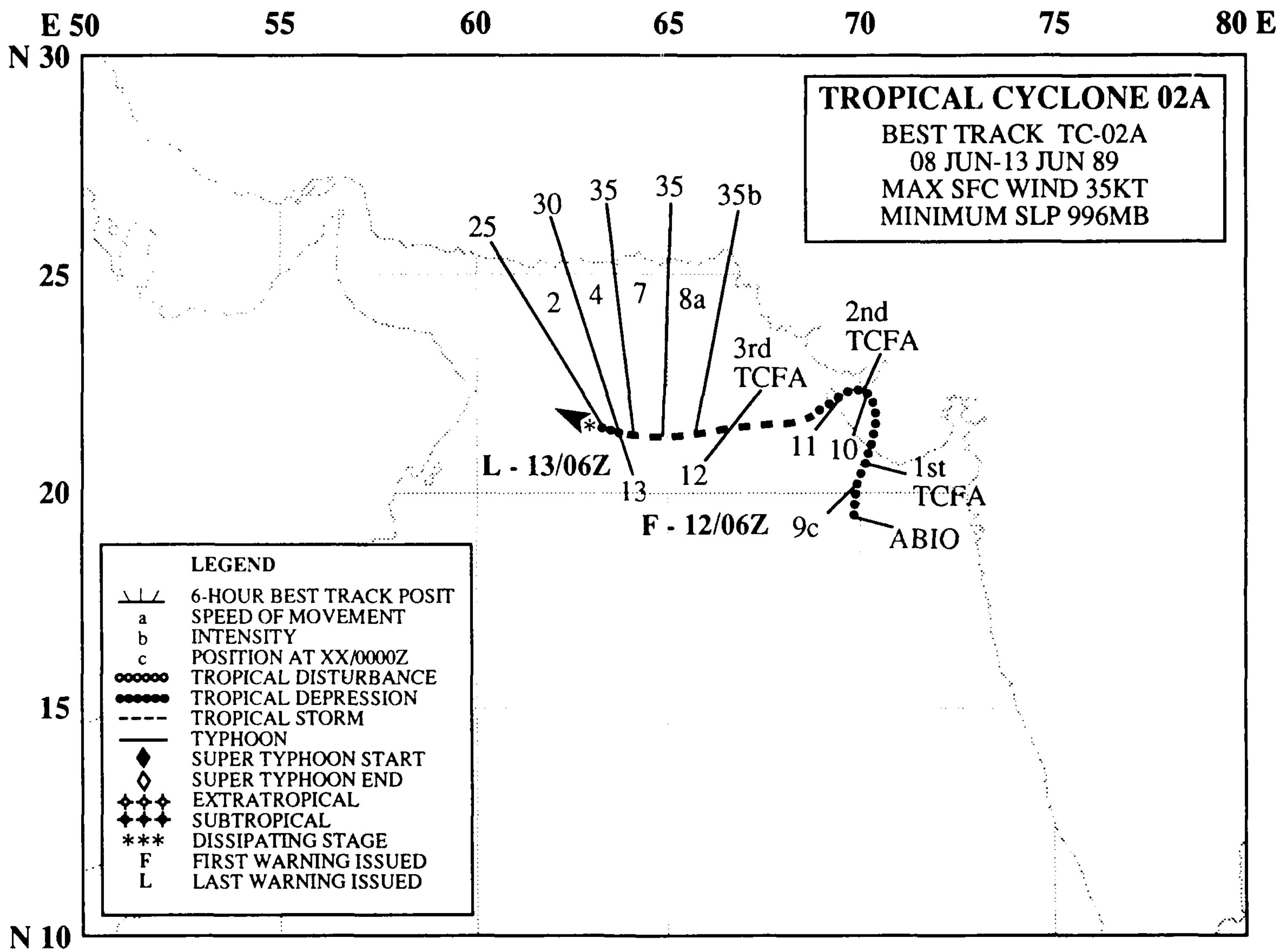


Figure 3-01B-1. Digitized mosaic from the satellite global data base at AFGWC shows Tropical Cyclone 01B moving towards landfall and Calcutta (240300Z-240400Z May DMSP visual data).



E 50
55
60
65
70
75
80 E
N 30
25
20
15
N 10
TROPICAL CYCLONE 02A
BEST TRACK TC-02A
08 JUN-13 JUN 89
MAX SFC WIND 35KT
MINIMUM SLP 996MB
25
30
35
35
35b
2
4
7
8a
3rd TCFA
2nd TCFA
1st TCFA
ABIO
9c
10
11
12
13
L - 13/06Z
F - 12/06Z
LEGEND
6-HOUR BEST TRACK POSIT
a SPEED OF MOVEMENT
b INTENSITY
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TROPICAL CYCLONE 02A

The only significant tropical cyclone to develop in the Arabian Sea this year, Tropical Cyclone 02A, generated from a pre-existing low-level circulation beneath an area of weak upper-level divergence. The disturbance was first mentioned at 071800Z June on the Significant Tropical Weather Advisory. Subsequent satellite imagery indicated the convection was organizing as it tracked toward the northwestern coast of India. The first satellite fix was made at 090148Z, and it estimated the intensity to be 25 kt (13 m/sec). This prompted JTWC to issue a Tropical Cyclone Formation Alert at 090600Z. Although a day later the circulation was technically overland, the presence of enhanced convection overwater resulted in reissuance of the Alert at 100600Z. This Alert was later canceled as satellite and synoptic data showed that the circulation had remained overland for more than 24 hours.

At 111629Z, satellite imagery (Figure 3-02A-1) revealed that the deep convection had moved rapidly westward into the Arabian Sea as an upper-level anticyclone advanced from the Arabian peninsula into Afghanistan and increased the eastern flow aloft over the Arabian Sea. A third Alert followed at 111800Z. Late arriving 110600Z ship observations reported 35 kt (18 m/sec) and a 998 mb pressure near the circulation center. Rapidly increasing convection and low-level organization led to an Abbreviated Warning at 120600Z. Mid-level flow around the subtropical ridge over Iran and Afghanistan carried the cyclone westward, but the strong northeasterly upper-level flow from the anticyclone aloft restricted its outflow and suppressed further development. The last warning was issued at 130600Z when satellite imagery indicated that the convection had separated more than 60 nm (110 km) to the west of the low-level circulation.

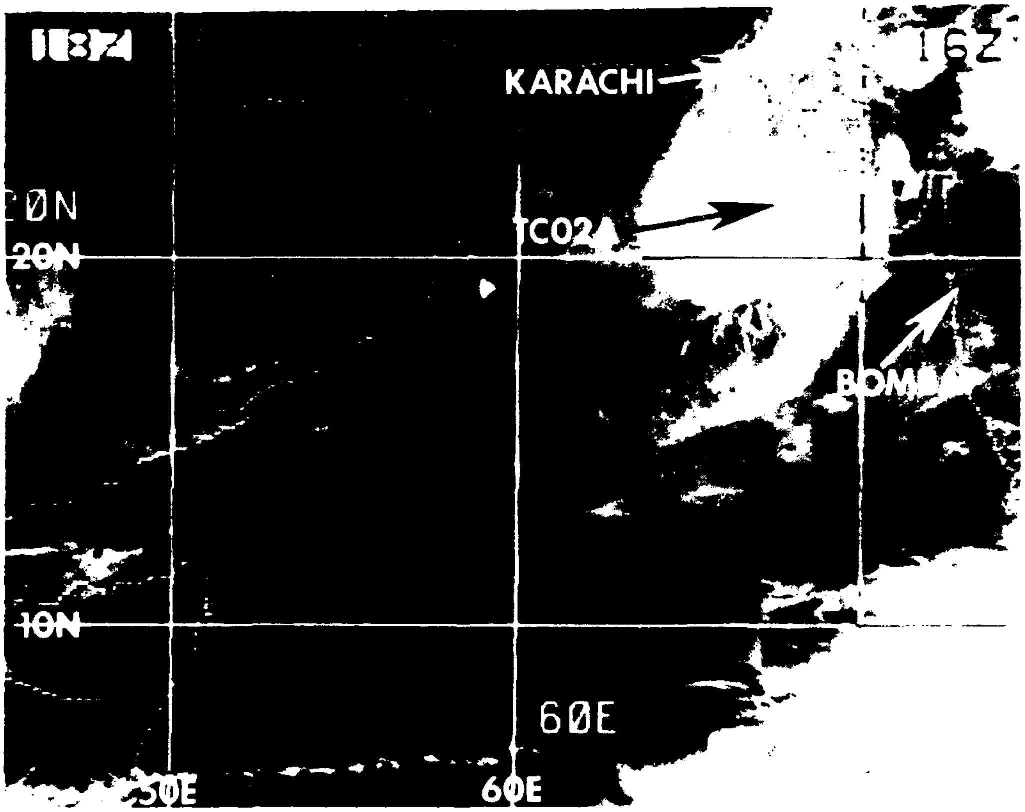


Figure 3-02A-1. A digitized mosaic of satellite data shows Tropical Cyclone 02A over the Arabian Sea (111600Z to 111800Z June DMSP infrared imagery).

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4. SUMMARY OF SOUTH PACIFIC AND SOUTH INDIAN OCEAN TROPICAL CYCLONES

4.1 GENERAL

On 1 October 1980 JTWC's area of responsibility (AOR) was expanded to include the Southern Hemisphere from 180° longitude westward to the coast of Africa. Details on Southern Hemisphere tropical cyclones and JTWC warnings from July 1980 through June 1982 are contained in Diercks *et al.* (1982) and from July 1982 through June 1984, in Wirfel and Sandgathe (1986). Information on Southern Hemisphere tropical cyclones after June 1984 can be found in the applicable Annual Tropical Cyclone Report.

The Naval Western Oceanography Center (NWOC) Pearl Harbor, HI issues warnings on tropical cyclones in the South Pacific east of 180° longitude. Tropical cyclones in NWOC's AOR are included in this and previous Annual Tropical Cyclone Reports.

In accordance with USCINCPACINST 3140.1 (series), Southern Hemisphere tropical cyclones are numbered sequentially from 1 July through 30 June. This convention is established to encompass the Southern Hemisphere tropical cyclone season, which normally occurs from January through April. There are two ocean basins for warning purposes - the South Indian (west of 135° east longitude) and the South Pacific (east of 135° east longitude) - which are identified by appending the suffixes "S" and "P" respectively to the tropical cyclone number.

CAVEAT: Intensity estimates for Southern Hemisphere tropical cyclones are derived from the evaluation of satellite imagery (Dvorak, 1984) and in rare instances by surface observations. Estimates for minimum sea-level pressure are derived by applying the Atkinson and Holliday (1977) relationship between maximum sustained one-minute average surface wind and minimum sea-level pressure (Table 4-1) to the intensity estimates derived from satellite imagery. Note: This relationship was based on data from the western North Pacific. A modified relationship has been adopted for the Atlantic basin.

4.2 SOUTH PACIFIC AND INDIAN OCEAN TROPICAL CYCLONES

After a below average number of tropical cyclones in 1988, 1989 (Table 4-2) activity rose to the near climatological mean of 27 storms (Table 4-3). A comparison of tropical cyclone activity for these two years shows that both started in the beginning of November and ended by mid-May. Although December 1989 proved to be below average with only one tropical cyclone in a month which normally has three, the multiple outbreaks (Figure 4-1) in late February and in the late March/early April timeframe resulted in the total being near normal. During the year, two tropical cyclones achieved super typhoon intensity—Harry (10P) and Orson (26S). Harry (10P) also shared the

TABLE 4-1 **MAXIMUM SUSTAINED SURFACE WINDS AND EQUIVALENT MINIMUM SEA-LEVEL PRESSURE (ATKINSON AND HOLLIDAY, 1977)**

MAXIMUM SUSTAINED SURFACE WIND (KT)	MINIMUM SEA-LEVEL PRESSURE (MB)
30	1000
35	997
40	994
45	991
50	987
55	984
60	980
65	976
70	972
75	967
80	963
85	958
90	954
95	948
100	943
105	938
110	933
115	927
120	922
125	916
130	910
135	906
140	898
145	892

distinction of requiring warnings for almost two weeks with Barisaona (02S) and Hanitra (11S). A comparison of activity by basin appears in Table 4-4. Plots of the tropical cyclone best tracks are provided in Figures 4-2 and 4-3.

TABLE 4-2

SOUTH PACIFIC AND SOUTH INDIAN OCEANS
1989 SIGNIFICANT TROPICAL CYCLONES
(1 July 1988 - 30 June 1989)

TROPICAL CYCLONE	PERIOD OF WARNING	NUMBER WARNINGS ISSUED	MAXIMUM SURFACE WINDS-KT (M/SEC)	ESTIMATED MSLP (MB)
01S ADELININA	01 NOV - 04 NOV	9	75 (39)	968***
02S BARISAONA	08 NOV - 20 NOV	26	100 (51)	944***
03S ILONA	13 DEC - 18 DEC	10	85 (44)	958
04P DELILAH	01 JAN - 03 JAN	4	60 (31)	980
05P GINA	07 JAN - 09 JAN	6**	45 (23)	991
06S - - - -	10 JAN - 14 JAN	9	75 (39)	968***
07S EDME	20 JAN - 25 JAN	11	115 (59)	927
08S FIRINGA	26 JAN - 01 FEB	14	90 (46)	954
09S KIRRILY	06 FEB - 10 FEB	9	75 (39)	967
10P HARRY	08 FEB - 19 FEB	24	130 (67)	910
11S HANITRA	17 FEB - 28 FEB	23	125 (64)	916
12S GIZELA	18 FEB - 22 FEB	9	65 (33)	976
13P IVY	23 FEB - 01 MAR	13	100 (51)	944***
14P - - - -	24 FEB - 01 MAR	10**	90 (46)	954
15P JUDY	24 FEB - 28 FEB	9**	90 (46)	954
16S - - - -	24 FEB - 25 FEB	3	45 (23)	991
17S MARCIA	03 MAR - 04 MAR	3	35 (18)	987***
18S - - - -	09 MAR - 10 MAR	4	35 (18)	997
19S JINARO	25 MAR - 30 MAR	13	65 (33)	976
20S NED	26 MAR - 31 MAR	19	100 (51)	943
21S KRISSY	30 MAR - 07 APR	18	105 (54)	938
22P KERRY	31 MAR - 02 APR	5	50 (26)	987
23P AIVU	01 APR - 04 APR	8	120 (62)	922
24S LEZISSY	06 APR - 09 APR	6	45 (23)	991
25P LILI	07 APR - 11 APR	10	110 (57)	933
26S ORSON	18 APR - 23 APR	12	140 (72)	898
27P MEENA	03 MAY - 10 MAY	16	50 (26)	987
28P ERNIE	07 MAY - 09 MAY	5	35 (18)	997
28P ERNIE*	10 MAY - 12 MAY	4	30 (15)	1000
	TOTAL	312		

* REGENERATED
** ISSUED BY NWOC
*** BASED ON SYNOPTIC DATA

NOTE: NAMES OF SOUTHERN HEMISPHERE TROPICAL CYCLONES ARE GIVEN BY THE REGIONAL WARNING CENTERS (NADI, BRISBANE, DARWIN, PERTH, REUNION AND MAURITIUS) AND ARE APPENDED TO JTWC WARNINGS, WHEN AVAILABLE.

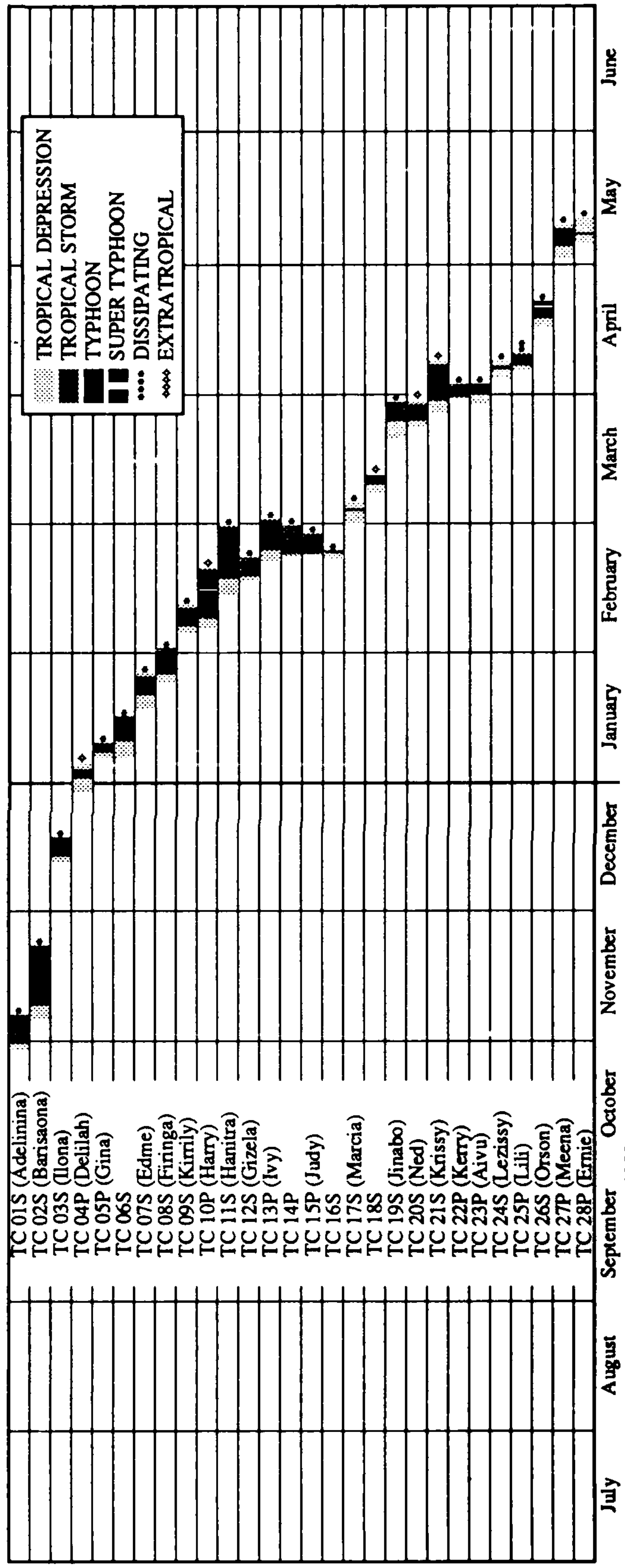


Figure 4-1. Chronology of South Pacific and South Indian Ocean tropical cyclones for 1989.

TABLE 4-3 **TROPICAL CYCLONE DISTRIBUTION SOUTH PACIFIC AND SOUTH INDIAN OCEANS**

YEAR	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	TOTAL
(1959-1978) AVERAGE*	-	-	-	0.4	1.5	3.6	6.1	5.8	4.7	2.1	0.5	-	24.7
1981	0	0	0	1	3	2	6	5	3	3	1	0	24
1982	1	0	0	1	1	3	9	4	2	3	1	0	25
1983	1	0	0	1	1	3	5	6	3	5	0	0	25
1984	1	0	0	1	2	5	5	10	4	2	0	0	30
1985	0	0	0	0	1	7	9	9	6	3	0	0	35
1986	0	0	1	0	1	1	9	9	6	4	2	0	33
1987	0	1	0	0	1	3	6	8	3	4	1	1	28
1988	0	0	0	0	2	3	5	5	3	1	2	0	21
1989	0	0	0	0	2	1	5	8	6	4	2	0	28
TOTAL CASES:	3	1	1	4	14	28	59	64	36	29	9	1	249
(1981-1989) AVERAGE:	0.3	0.1	0.1	0.4	1.6	3.1	6.6	7.1	4.0	3.2	1.0	0.1	27.7

* (GRAY, 1979)

TABLE 4-4 **ANNUAL VARIATION OF SOUTHERN HEMISPHERE TROPICAL CYCLONES BY OCEAN BASIN**

YEAR	SOUTH INDIAN (WEST OF 105° E)	AUSTRALIAN (105° E - 165° E)	SOUTH PACIFIC (EAST OF 165° E)	TOTAL
(1959-1978) AVERAGE*	8.4	10.3	5.9	24.7
1981	13	8	3	24
1982	12	11	2	25
1983	7	6	12	25
1984	14	14	2	30
1985	14	15	6	35
1986	14	16	3	33
1987	9	8	11	28
1988	14	2	5	21
1989	12	9	7	28
TOTAL CASES:	109	89	51	249
(1981-1989) AVERAGE:	12.1	9.9	5.7	27.7

* (GRAY, 1979)

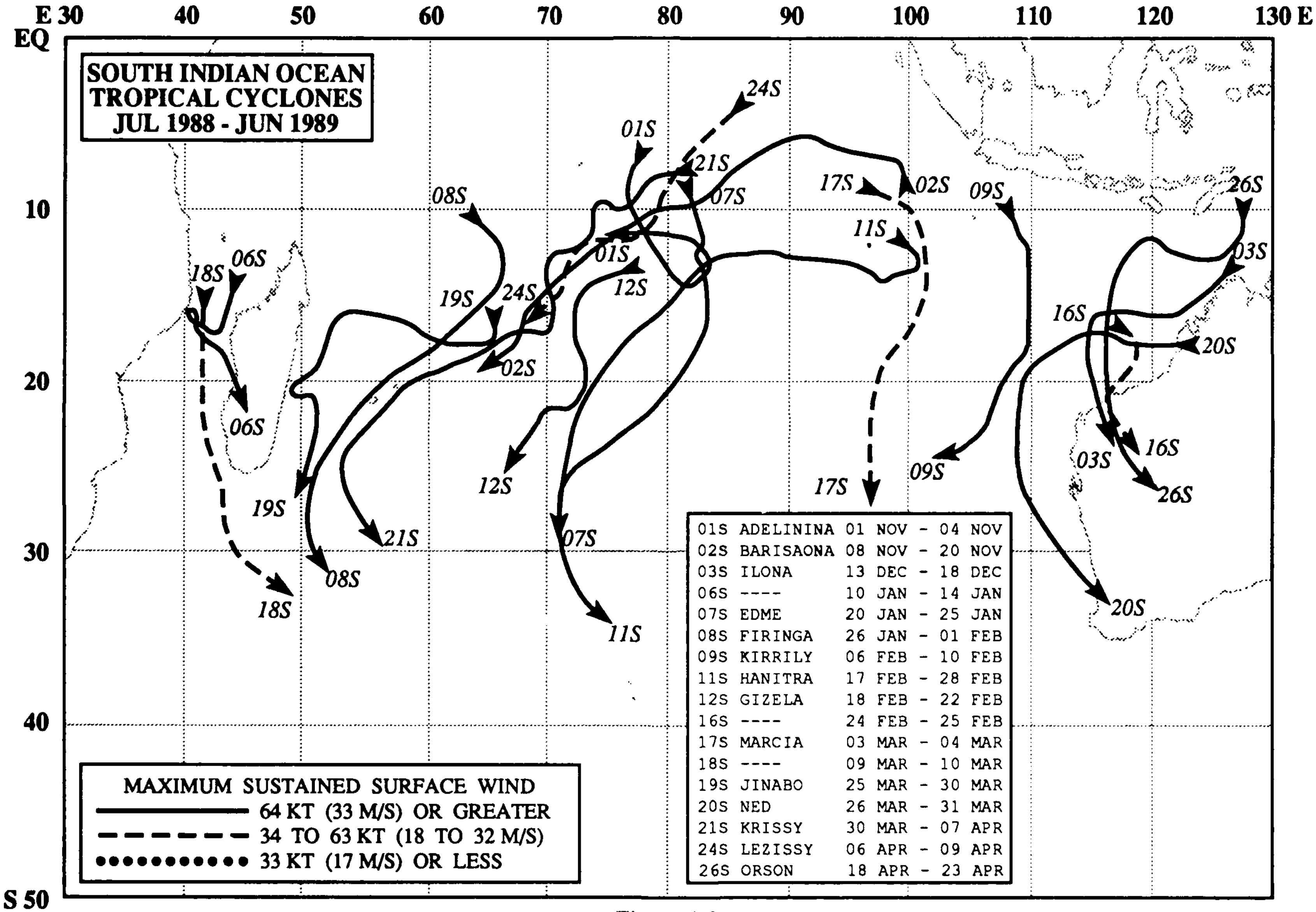
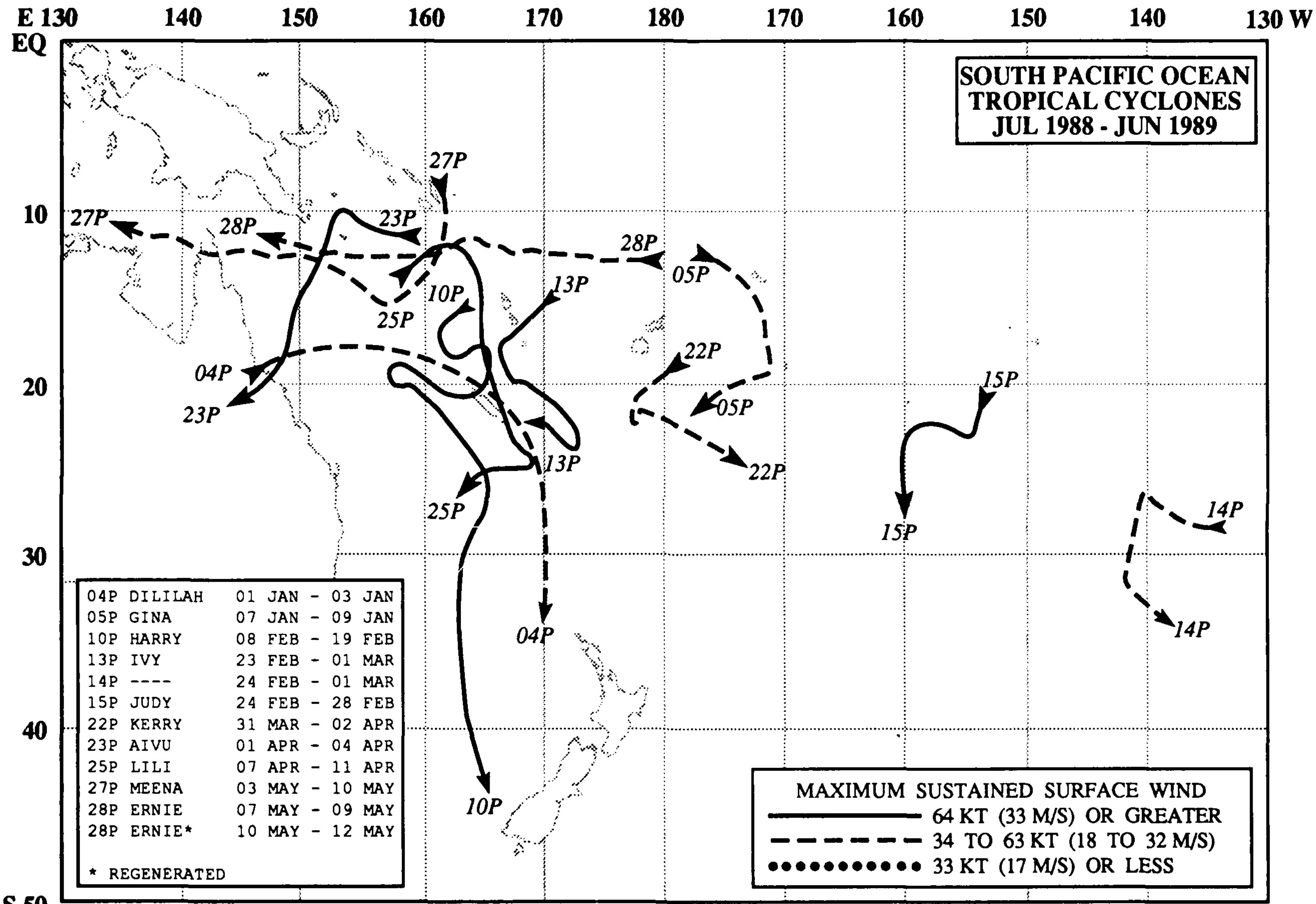

SOUTH INDIAN OCEAN
TROPICAL CYCLONES
JUL 1988 - JUN 1989
E 30
40
50
60
70
80
90
100
110
120
130 E
EQ
10
20
30
40
S 50
MAXIMUM SUSTAINED SURFACE WIND
64 KT (33 M/S) OR GREATER
34 TO 63 KT (18 TO 32 M/S)
33 KT (17 M/S) OR LESS
01S ADELININA 01 NOV - 04 NOV
02S BARISAONA 08 NOV - 20 NOV
03S ILONA 13 DEC - 18 DEC
06S ---- 10 JAN - 14 JAN
07S EDME 20 JAN - 25 JAN
08S FIRINGA 26 JAN - 01 FEB
09S KIRRILY 06 FEB - 10 FEB
11S HANITRA 17 FEB - 28 FEB
12S GIZELA 18 FEB - 22 FEB
16S ---- 24 FEB - 25 FEB
17S MARCIA 03 MAR - 04 MAR
18S ---- 09 MAR - 10 MAR
19S JINABO 25 MAR - 30 MAR
20S NED 26 MAR - 31 MAR
21S KRISSY 30 MAR - 07 APR
24S LEZISSY 06 APR - 09 APR
26S ORSON 18 APR - 23 APR

Figure 4-2



SOUTH PACIFIC OCEAN
TROPICAL CYCLONES
JUL 1988 - JUN 1989
E 130
140
150
160
170
180
170
160
150
140
130 W
EQ
10
20
30
40
S 50
04P DILILAH 01 JAN - 03 JAN
05P GINA 07 JAN - 09 JAN
10P HARRY 08 FEB - 19 FEB
13P IVY 23 FEB - 01 MAR
14P ---- 24 FEB - 01 MAR
15P JUDY 24 FEB - 28 FEB
22P KERRY 31 MAR - 02 APR
23P AIVU 01 APR - 04 APR
25P LILI 07 APR - 11 APR
27P MEENA 03 MAY - 10 MAY
28P ERNIE 07 MAY - 09 MAY
28P ERNIE* 10 MAY - 12 MAY
* REGENERATED
MAXIMUM SUSTAINED SURFACE WIND
64 KT (33 M/S) OR GREATER
34 TO 63 KT (18 TO 32 M/S)
33 KT (17 M/S) OR LESS

Figure 4-3

5. SUMMARY OF FORECAST VERIFICATION

5.1 ANNUAL FORECAST VERIFICATION

5.1.1 WESTERN NORTH PACIFIC OCEAN — Verification of warnings at initial, 24-, 48- and 72-hour forecast positions was made against the final best track. The (scalar) forecast, along-track and cross-track errors (illustrated in Figure 5-1) were then calculated for each tropical cyclone and are presented in Tables 5-1A, 5-1B, 5-1C and 5-1D, as appropriate. Table 5-2 includes mean along-track and cross-track forecast errors for 1978-1989. The frequency distributions of errors for warning positions, and 24-, 48-, and 72-hour forecasts are in Figures 5-2A through 5-2D, respectively. A comparison of the annual mean forecast errors for all tropical cyclones as compared to those tropical cyclones that reached typhoon intensity can be seen in Table 5-3. The mean forecast errors for 1989 as compared to the twenty previous years are graphed in Figure 5-3.

5.1.2 NORTH INDIAN OCEAN — The positions given for warning times and those at the 24-, 48-, and 72-hour valid times were verified for tropical cyclones in the North Indian Ocean by the same methods used for the western North Pacific. Table 5-4 is the initial and forecast along-track and cross-track error summary for the North Indian Ocean. Forecast errors are plotted in Figure 5-4 (72-hour forecast errors were evaluated for the first time in 1979). There were no verifying 72-hour forecasts in 1983 and 1985. Table 5-5 contains a summary of the annual mean forecast errors for each year.

5.1.3 SOUTH PACIFIC AND SOUTH INDIAN OCEANS — The positions given for warning times and those at the 24-, 48-, and 72-hour valid times were verified for tropical cyclones in the Southern Hemisphere by the same methods used for the western North Pacific. Table 5-6A is the initial, forecast along-track and cross-track error summary for the Southern Hemisphere. Table 5-6B has the number of warnings verified at each forecast period. Forecast errors are plotted in Figure 5-5. Table 5-7 contains a summary of the annual mean forecast errors.

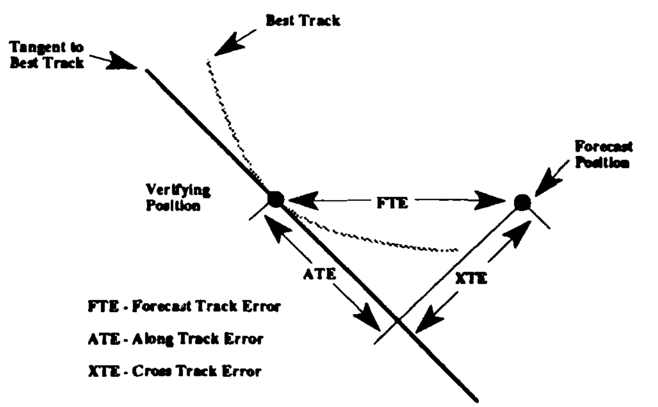


Figure 5-1. Definition of cross-track error (XTE), along-track error (ATE) and forecast track error (FTE). In this example, the XTE is positive (to the right of the best track) and the ATE is negative (behind or slower than the best track).

TABLE 5-1A **INITIAL POSITION ERRORS (NM)**
WESTERN NORTH PACIFIC OCEAN
1989 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE			ERROR (NM)	NUMBER OF WARNINGS
(01W)	TS	WINONA	25	13
(02W)	STY	ANDY	12	26
(03W)	TY	BRENDA	31	20
(04W)	TY	CECIL	19	9
(05W)	TY	DOT	16	25
(06W)	TS	ELLIS	33	6
(07W)	TS	FAYE	25	21
(08W)	STY	GORDON	13	30
(09W)	TS	HOPE	21	21
(10W)	TS	IRVING	21	14
(11W)	TY	JUDY	15	28
(12W)	TD	12W	14	3
(13W-14W)	TS	KEN-LOLA	38	23
(15W)	TY	MAC	17	28
(16W)	TY	OWEN	21	28
(17W)	TY	NANCY	19	22
(18W)	TS	PEGGY	24	9
(19W)	TD	19W	19	6
(20W)	TS	ROGER	32	14
(21W)	TD	21W	23	7
(22W)	TY	SARAH	28	33
(23W)	TS	TIP	23	20
(24W)	TS	VERA	25	16
(25W)	TY	WAYNE	19	12
(26W)	STY	ANGELA	8	46
(27W)	TY	BRIAN	16	13
(28W)	TY	COLLEEN	18	27
(29W)	TY	DAN	16	21
(30W)	STY	ELSIE	12	34
(31W)	TY	FORREST	22	30
(32W)	TY	GAY	6	9
(33W)	TY	HUNT	14	27
(34W)	STY	IRMA	18	39
(35W)	TD	35W	73	9
(36W)	TY	JACK	28	21
			MEAN: 20	**TOTAL**: 710

TABLE 5-1B

24-HOUR FORECAST ERRORS (NM)
WESTERN NORTH PACIFIC OCEAN
1989 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE	FORECAST ERROR (NM)	ALONG-TRACK ERROR MEAN*	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN*	CROSS-TRACK ERROR MEDIAN	SAMPLE SIZE
(01W) TS WINONA	171	152	**	88	**	10
(02W) STY ANDY	111	77	-44	65	-18	26
(03W) TY BRENDA	133	103	-78	68	14	18
(04W) TY CECIL	127	64	**	108	**	8
(05W) TY DOT	78	55	-10	48	30	23
(06W) TS ELLIS	347	294	**	126	**	6
(07W) TS FAYE	72	48	-28	41	-12	18
(08W) STY GORDON	68	41	21	47	5	26
(09W) TS HOPE	112	39	25	101	-10	17
(10W) TS IRVING	91	73	**	41	**	9
(11W) TY JUDY	85	55	-32	54	34	24
(12W) TD 12W	61	32	**	52	**	2
(13W-14W) TS KEN-LOLA	195	114	-115	124	-61	18
(15W) TY MAC	167	126	-83	86	-13	26
(16W) TY OWEN	115	78	-60	66	9	27
(17W) TY NANCY	146	127	-98	52	-34	20
(18W) TS PEGGY	143	91	**	100	**	8
(19W) TD 19W	95	60	**	53	**	4
(20W) TS ROGER	223	192	-167	97	-80	12
(21W) TD 21W	135	107	**	55	**	6
(22W) TY SARAH	165	95	-37	122	-16	29
(23W) TS TIP	204	110	-74	152	-127	18
(24W) TS VERA	173	145	-135	68	-25	13
(25W) TY WAYNE	231	201	**	105	**	10
(26W) STY ANGELA	68	46	-17	40	15	43
(27W) TY BRIAN	104	69	**	52	**	10
(28W) TY COLLEEN	153	116	-68	74	-35	24
(29W) TY DAN	105	88	-55	38	-10	18
(30W) STY ELSIE	75	48	-37	44	-15	31
(31W) TY FORREST	93	61	-5	56	-37	27
(32W) TY GAY	46	25	**	30	**	9
(33W) TY HUNT	98	64	6	58	-44	25
(34W) STY IRMA	97	69	-37	53	-32	35
(35W) TD 35W	212	79	**	192	**	5
(36W) TY JACK	95	55	-11	67	-31	20
MEAN:	120	83		69		**TOTAL:** 625
MEDIAN:	119	-47		-13		
STANDARD DEVIATION:	83	105		90		

* THE MEAN WAS COMPUTED FROM ABSOLUTE VALUES.
** THE MEDIAN WAS NOT COMPUTED FOR INSTANCES OF TEN CASES OR LESS.

1. THE MEAN IS THE SUM OF ALL THE VALUES DIVIDED BY THE NUMBER OF OBSERVATIONS.
2. THE MEDIAN IS THE MIDDLE VALUE OF THE SAMPLE, ESTIMATED THROUGH A GAMMA PROBABILITY DISTRIBUTION.
3. THE ALONG-TRACK ERROR COMPONENT IS HOW FAR THE WARNING POSITION WAS DISPLACED AHEAD OR BEHIND THE BEST TRACK POSITION. THE SAMPLE CONSISTS OF TWO PARTS: THE MEAN (DISTANCE) AND THE MEDIAN (NEGATIVE VALUES WERE BEHIND TRACK OR SLOW, AND POSITIVE VALUES WERE AHEAD OF TRACK OR FAST).
4. THE CROSS-TRACK ERROR COMPONENT IS HOW FAR THE WARNING POSITION WAS DISPLACED TO THE LEFT OR RIGHT OF THE BEST TRACK POSITION. THE SAMPLE CONSISTS OF TWO PARTS: THE MEAN (DISTANCE) AND THE MEDIAN (NEGATIVE VALUES WERE LEFT OF TRACK AND POSITIVE VALUES WERE RIGHT OF TRACK).

TABLE 5-1C

48-HOUR FORECAST ERRORS (NM)
WESTERN NORTH PACIFIC OCEAN
1989 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE		FORECAST ERROR (NM)	ALONG-TRACK ERROR MEAN*	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN*	CROSS-TRACK ERROR MEDIAN	SAMPLE SIZE
(01W)	TS WINONA	346	322	**	118	**	6
(02W)	STY ANDY	290	205	-167	174	-74	22
(03W)	TY BRENDA	227	178	-180	104	48	12
(04W)	TY CECIL	330	80	**	318	**	6
(05W)	TY DOT	148	113	-8	80	73	17
(06W)	TS ELLIS	***	***	***	***	***	0
(07W)	TS FAYE	124	106	-106	54	-12	12
(08W)	STY GORDON	118	65	30	85	23	24
(09W)	TS HOPE	224	111	82	172	-57	14
(10W)	TS IRVING	152	133	**	44	**	4
(11W)	TY JUDY	195	98	-92	144	107	20
(12W)	TD 12W	***	***	***	***	***	0
(13W-14W)	TS KEN-LOLA	313	180	-106	225	-194	14
(15W)	TY MAC	335	244	-146	198	-132	23
(16W)	TY OWEN	239	189	-151	108	37	23
(17W)	TY NANCY	348	294	-266	110	12	19
(18W)	TS PEGGY	335	147	**	281	**	6
(19W)	TD 19W	***	***	***	***	***	0
(20W)	TS ROGER	474	459	**	94	**	7
(21W)	TD 21W	***	***	***	***	***	0
(22W)	TY SARAH	302	140	5	240	-18	25
(23W)	TS TIP	374	206	-193	270	-190	11
(24W)	TS VERA	381	373	**	69	**	10
(25W)	TY WAYNE	623	564	**	253	**	4
(26W)	STY ANGELA	165	112	-51	96	73	39
(27W)	TY BRIAN	135	79	**	93	**	5
(28W)	TY COLLEEN	207	132	-25	135	-75	20
(29W)	TY DAN	222	202	-206	55	-29	13
(30W)	STY ELSIE	145	115	-90	66	-39	27
(31W)	TY FORREST	169	122	-16	85	-81	23
(32W)	TY GAY	101	87	**	39	**	8
(33W)	TY HUNT	173	123	41	103	-64	23
(34W)	STY IRMA	226	188	-179	104	-74	25
(35W)	TD 35W	440	30	**	439	**	1
(36W)	TY JACK	167	135	-14	83	-25	18
	MEAN:	231	162		127		**TOTAL:** 481
	MEDIAN:	227	-101		-19		
	STANDARD DEVIATION:	145	190		171		

* THE MEAN WAS COMPUTED FROM ABSOLUTE VALUES.
** THE MEDIAN WAS NOT COMPUTED FOR INSTANCES OF TEN CASES OR LESS.
*** FORECASTS WERE NOT ISSUED OR DID NOT VERIFY.

SEE TABLE 5-1B FOR EXPLANATIONS OF THE TERMS MEAN, MEDIAN, ALONG-TRACK ERROR AND CROSS-TRACK ERROR.

TABLE 5-1D

72-HOUR FORECAST ERRORS (NM)
WESTERN NORTH PACIFIC OCEAN
1989 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE		FORECAST ERROR (NM)	ALONG-TRACK ERROR MEAN*	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN*	CROSS-TRACK ERROR MEDIAN	SAMPLE SIZE
(01W)	TS WINONA	507	439	**	242	**	5
(02W)	STY ANDY	569	385	-352	378	-212	18
(03W)	TY BRENDA	251	188	**	142	**	9
(04W)	TY CECIL	***	***	***	***	***	0
(05W)	TY DOT	163	123	1	81	79	11
(06W)	TS ELLIS	***	***	***	***	***	0
(07W)	TS FAYE	220	213	**	49	**	10
(08W)	STY GORDON	146	111	75	75	9	18
(09W)	TS HOPE	309	145	**	259	**	5
(10W)	TS IRVING	232	227	**	45	**	2
(11W)	TY JUDY	323	190	-150	219	135	16
(12W)	TD 12W	***	***	***	***	***	0
(13W-14W)	TS KEN-LOLA	382	168	**	320	**	10
(15W)	TY MAC	520	352	-185	357	-136	19
(16W)	TY OWEN	380	336	-248	132	73	19
(17W)	TY NANCY	510	483	-489	132	21	16
(18W)	TS PEGGY	506	187	**	462	**	2
(19W)	TD 19W	***	***	***	***	***	0
(20W)	TS ROGER	949	921	**	233	**	3
(21W)	TD 21W	***	***	***	***	***	0
(22W)	TY SARAH	450	236	-30	322	-38	21
(23W)	TS TIP	502	440	**	206	**	8
(24W)	TS VERA	662	641	**	129	**	7
(25W)	TY WAYNE	***	***	***	***	***	0
(26W)	STY ANGELA	293	202	-117	178	149	35
(27W)	TY BRIAN	***	***	***	***	***	0
(28W)	TY COLLEEN	303	193	-78	189	-177	16
(29W)	TY DAN	376	359	**	89	**	10
(30W)	STY ELSIE	231	222	-155	58	-25	23
(31W)	TY FORREST	318	242	-228	138	-111	18
(32W)	TY GAY	197	185	**	57	**	8
(33W)	TY HUNT	208	156	112	103	-83	19
(34W)	STY IRMA	341	289	-300	146	-56	21
(35W)	TD 35W	***	***	***	***	***	0
(36W)	TY JACK	317	254	-32	159	105	14
	MEAN:	350	265		177		**TOTAL:** 363
	MEDIAN:	343	-182		-15		
	STANDARD DEVIATION:	206	287		236		

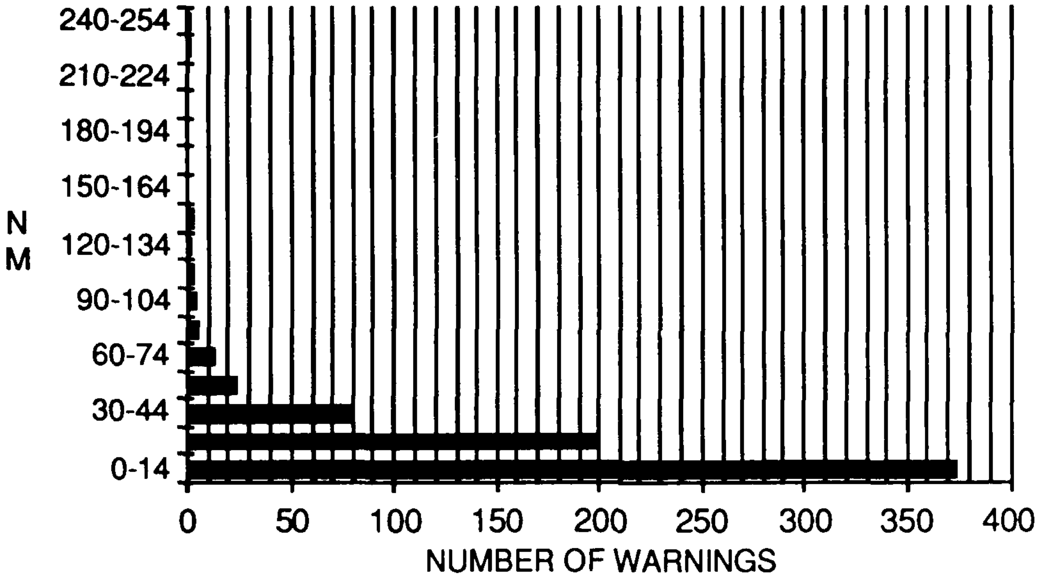
* THE MEAN WAS COMPUTED FROM ABSOLUTE VALUES.
** THE MEDIAN WAS NOT COMPUTED FOR INSTANCES OF TEN CASES OR LESS.
*** FORECASTS WERE NOT ISSUED OR DID NOT VERIFY.

SEE TABLE 5-1B FOR EXPLANATIONS OF THE TERMS MEAN, MEDIAN, ALONG-TRACK ERROR AND CROSS-TRACK ERROR.

TABLE 5-2. JTWC ANNUAL INITIAL POSITION AND FORECAST POSITION ERRORS (NM) 1978-1989 FOR THE WESTERN NORTH PACIFIC

		INITIAL	24 - HOUR				48 - HOUR				72 - HOUR			
YEAR	WARNINGS	POSITION	FORECASTS	TRACK	ALONG	CROSS	FORECASTS	TRACK	ALONG	CROSS	FORECASTS	TRACK	ALONG	CROSS
1978	696	21	556	126	87	71	420	274	194	151	295	411	296	218
1979	695	25	589	125	81	76	469	227	146	138	366	316	214	182
1980	590	28	491	127	86	76	369	244	165	147	267	391	266	230
1981	584	25	466	124	80	77	348	221	146	131	246	334	206	219
1982	786	19	666	113	74	70	532	238	162	142	425	342	223	211
1983	445	16	342	117	76	73	253	260	169	164	184	407	259	263
1984	611	22	492	117	84	64	378	232	163	131	286	363	238	216
1985	592	18	477	117	80	68	336	231	153	138	241	367	230	227
1986	743	21	645	126	85	70	535	261	183	151	412	394	276	227
1987	657	18	563	107	71	64	465	204	134	127	389	303	198	186
1988	465	23	373	114	85	58	262	216	170	103	183	315	244	159
TOTALS:	6864		5660				4367				3294			
AVERAGE 78-88:	624	21	515	120	81	70	397	238	162	139	299	356	239	211
1989	710	20	625	120	83	69	481	231	162	127	363	350	265	177
TOTALS:	7574		6285				4848				3657			
AVERAGE 78-89:	631	21	524	120	81	70	404	237	162	138	305	355	242	208

Sources: 1978-85 24-, 48- & 72-hour errors from Tsui and Miller (1986)
Initial Position & 1986-89 errors from ATCR



MEAN: 20

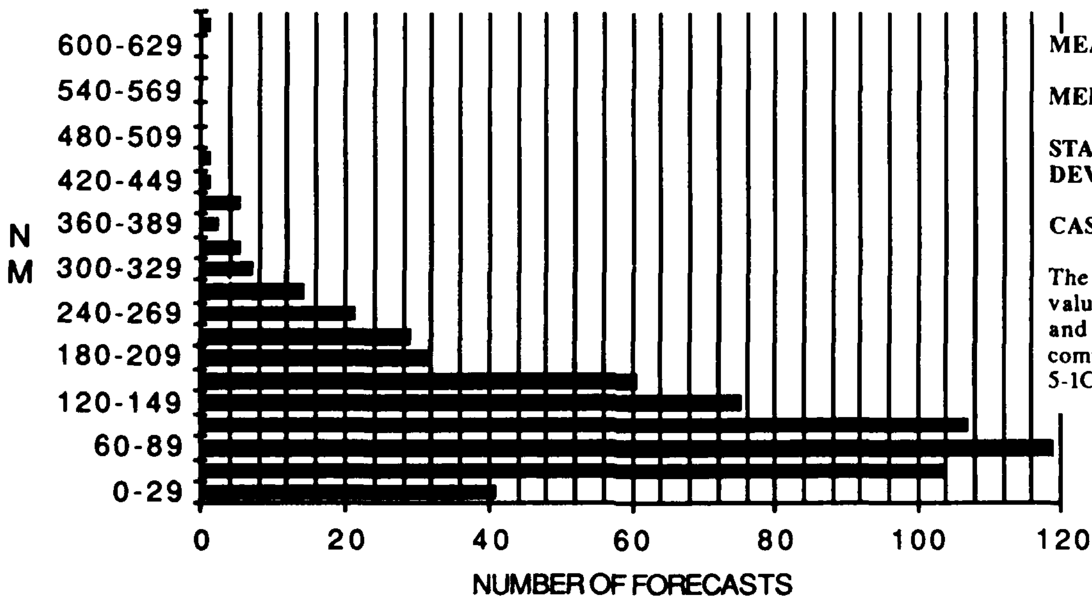
MEDIAN: 13

STANDARD DEVIATION: 22

CASES: 710

The median is the middle value obtained by sorting, and differs from median computed for Tables 5-1B, 5-1C,5-1D, 5-4 and 5-6A.

Figure 5-2A. Frequency distribution of initial position errors (15 nm increments) for the western North Pacific in 1989.



MEAN: 120

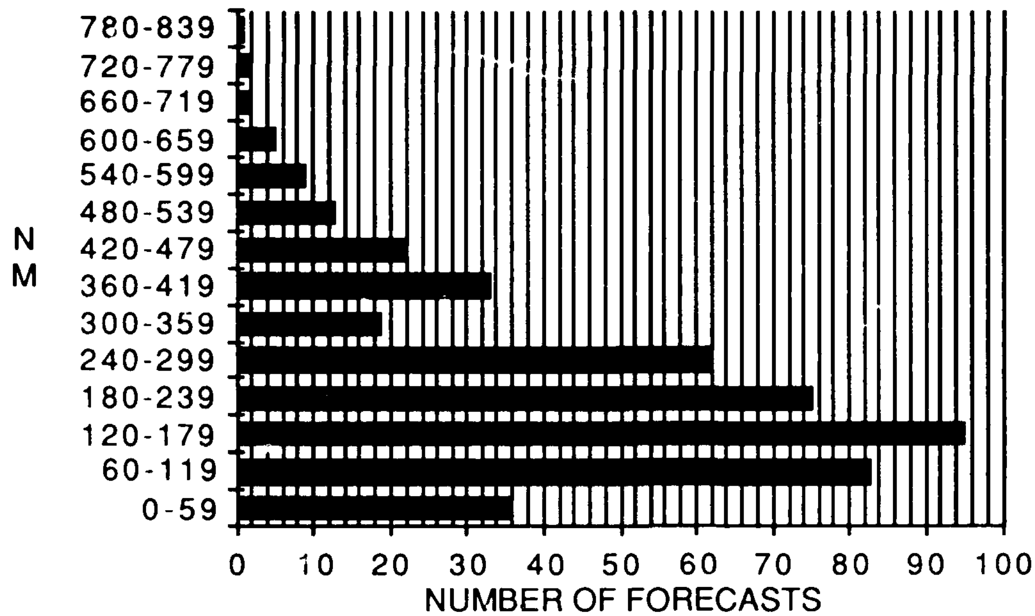
MEDIAN: 102.5

STANDARD DEVIATION: 83

CASES: 625

The median is the middle value obtained by sorting, and differs from median computed for Tables 5-1B, 5-1C,5-1D, 5-4 and 5-6A.

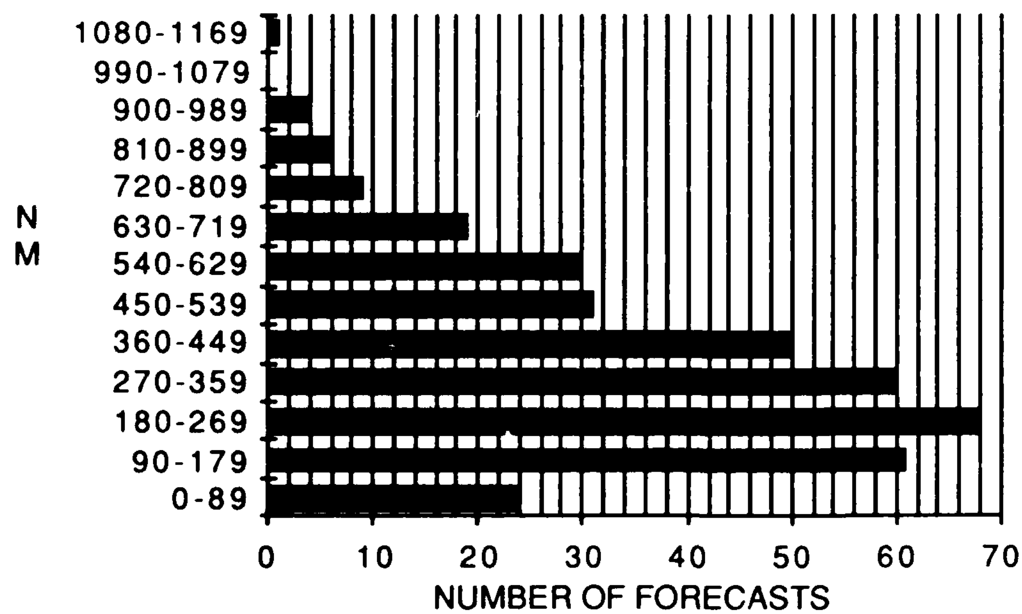
Figure 5-2B. Frequency distribution of 24-hour forecast errors (30 nm increments) for the western North Pacific in 1989.



MEAN:	231
MEDIAN:	203
STANDARD DEVIATION:	145
CASES:	481

The median is the middle value obtained by sorting, and differs from median computea for Tables 5-1B, 5-1C,5-1D, 5-4 and 5-6A.

Figure 5-2C. Frequency distribution of 48-hour forecast errors (60 nm increments) for the western North Pacific in 1989.



MEAN:	350
MEDIAN:	307
STANDARD DEVIATION:	206
CASES:	363

The median is the middle value obtained by sorting, and differs from median computed for Tables 5-1B, 5-1C,5-1D, 5-4 and 5-6A.

Figure 5-2D. Frequency distribution of 72-hour forecast errors (90 nm increments) for the western North Pacific in 1989.

TABLE 5-3 **ANNUAL MEAN FORECAST ERRORS (NM)**
WESTERN NORTH PACIFIC

YEAR	24-HOUR ALL	24-HOUR TYPHOONS*	48-HOUR ALL	48-HOUR TYPHOONS*	72-HOUR ALL	72-HOUR TYPHOONS*
1959		117**		267**		
1960		177**		354**		
1961		136		274		
1962		144		287		476
1963		127		246		374
1964		133		284		429
1965		151		303		418
1966		136		280		432
1967		125		276		414
1968		105		229		337
1969		111		237		349
1970	104	98	190	181	279	272
1971	111	99	212	203	317	308
1972	117	116	245	245	381	382
1973	108	102	197	193	253	245
1974	120	114	226	218	348	357
1975	138	129	288	279	450	442
1976	117	117	230	232	338	336
1977	148	140	283	266	407	390
1978	127	120	271	241	410	459
1979	124	113	226	219	316	319
1980	126	116	243	221	389	362
1981	123	117	220	215	334	342
1982	113	114	237	229	341	337
1983	117	110	259	247	405	384
1984	117	110	233	228	363	361
1985	117	112	231	228	367	355
1986	121	117	261	261	394	403
1987	107	101	204	211	303	318
1988	114	107	216	222	315	327
1989	120	107	231	214	350	325

* FORECASTS WERE VERIFIED WHEN THE TROPICAL CYCLONE INTENSITIES WERE AT LEAST 35 KT (18 M/SEC).

** FORECAST POSITIONS NORTH OF 35 DEGREES NORTH LATITUDE WERE NOT VERIFIED.

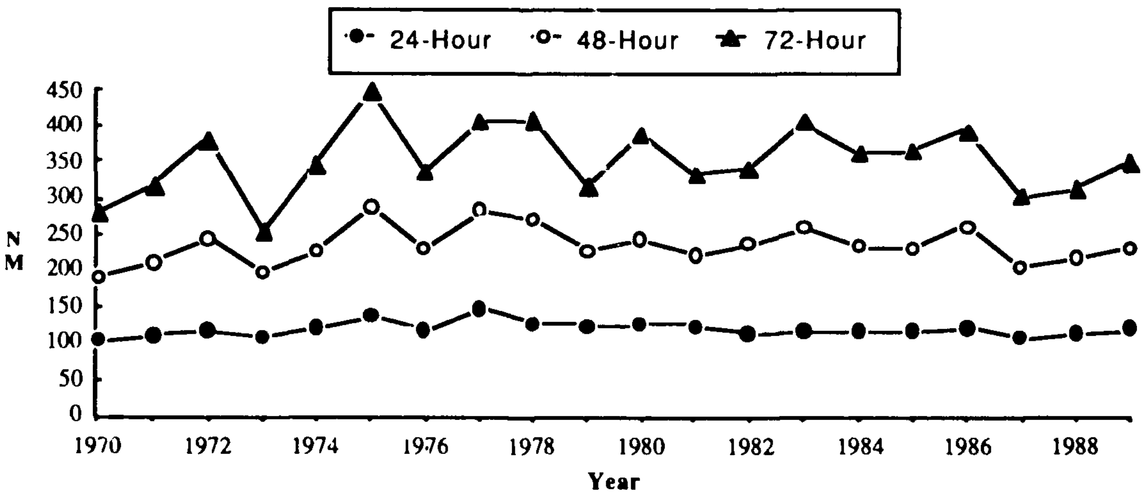


Figure 5-3. Annual mean forecast errors (nm) for all significant tropical cyclones in the western North Pacific.

TABLE 5-4

INITIAL POSITION AND FORECAST ERRORS (NM)
FOR THE NORTH INDIAN OCEAN
1989 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE	INITIAL POSITION ERROR (NM)	NUMBER OF WARNINGS
TC 01B	23	14
TC 02A	41	5
TC 32W	13	25
TOTAL	--	44
MEAN	19	--
STANDARD DEVIATION	15	--

24-HOUR FORECASTS

TROPICAL CYCLONE	FCST ERROR	ALONG-TRACK ERROR MEAN	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN	CROSS-TRACK ERROR MEDIAN	SAMPLE SIZE
TC 01B	106	88	**	45	**	11
TC 02A	134	129	**	35	**	1
TC 32W	76	51	-52	43	-15	21
TOTAL	--	--		--		33
MEAN	88	62		50		--
MEDIAN	88	-32		-13		--
STANDARD DEVIATION	44	68		61		--

48-HOUR FORECASTS

TROPICAL CYCLONE	FCST ERROR	ALONG-TRACK ERROR MEAN	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN	CROSS-TRACK ERROR MEDIAN	SAMPLE SIZE
TC 01B	--	--	--	--	--	0
TC 02A	--	--	--	--	--	0
TC 32W	146	94	-95	86	-2	17
TOTAL	--	--		--		17
MEAN	146	94		86		--
MEDIAN	145	-95		-2		--
STANDARD DEVIATION	48	73		97		--

72-HOUR FORECASTS

TROPICAL CYCLONE	FCST ERROR	ALONG-TRACK ERROR MEAN	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN	CROSS-TRACK ERROR MEDIAN	SAMPLE SIZE
TC 01B	--	--	--	--	--	0
TC 02A	--	--	--	--	--	0
TC 32W	216	164	-166	111	-31	12
TOTAL	--	--		--		12
MEAN	216	164		111		--
MEDIAN	215	-166		-31		--
STANDARD DEVIATION	61	93		118		--

** THE MEDIAN WAS NOT COMPUTED FOR INSTANCES OF TEN CASES OR LESS.

SEE TABLE 5-1B FOR EXPLANATION OF THE TERMS MEAN, MEDIAN, ALONG-TRACK ERROR AND CROSS-TRACK ERROR.

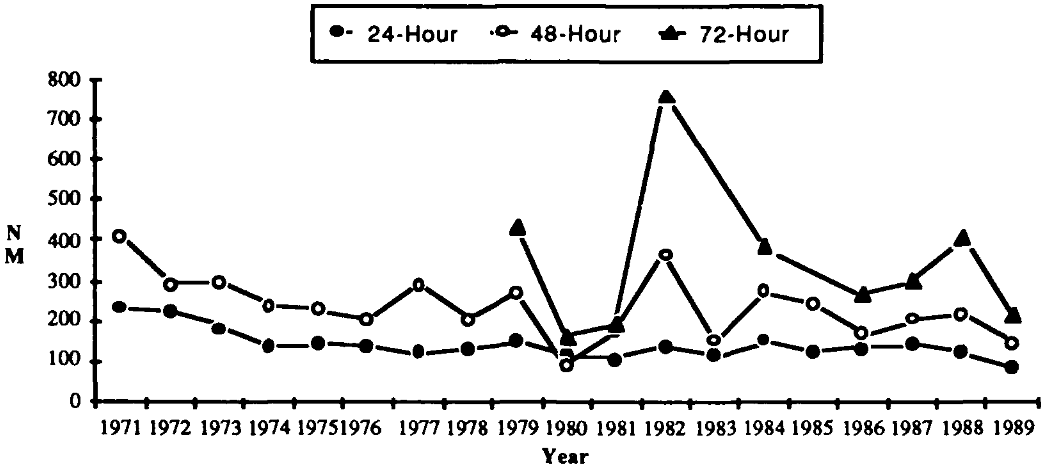


Figure 5-4. Annual mean forecast errors (nm) for all significant tropical cyclones in the North Indian Ocean.

TABLE 5-5

ANNUAL MEAN FORECAST ERRORS (NM) FOR THE NORTH INDIAN OCEAN

	24-HOUR		48-HOUR		72-HOUR	
YEAR	FORECAST	RIGHT-ANGLE	FORECAST	RIGHT-ANGLE	FORECAST	RIGHT-ANGLE
1971*	232	---	410	---	---	---
1972*	224	101	292	112	---	---
1973*	182	99	299	160	---	---
1974*	137	81	238	146	---	---
1975	145	99	228	144	---	---
1976	138	108	204	159	---	---
1977	122	94	292	214	---	---
1978	133	86	202	128	---	---
1979	151	99	270	202	437	371
1980	115	73	93	87	167	126
1981**	109	65	176	103	197	73
1982**	138	66	368	175	762	404
1983**	117	46	153	67	---	---
1984**	154	71	274	127	388	159
1985**	123	51	242	109	---	---
1986	134	***	168	***	269	***
1987	144	***	205	***	305	***
1988	120	***	219	***	409	***
1989	84	***	146	***	216	***

* THE WESTERN BAY OF BENGAL AND ARABIAN SEA WERE NOT INCLUDED IN THE JTWC AREA OF RESPONSIBILITY UNTIL THE 1975 TROPICAL CYCLONE SEASON.

** THE TECHNIQUE FOR CALCULATING RIGHT-ANGLE ERROR WAS REVISED IN 1981. THEREFORE, A DIRECT COMPARISON IN RIGHT-ANGLE ERROR STATISTICS CANNOT BE MADE BETWEEN ERRORS COMPUTED BEFORE 1981 AND THOSE COMPUTED SINCE 1981.

*** IN 1986, RIGHT-ANGLE ERROR WAS REPLACED BY CROSS-TRACK ERROR. (SEE

TABLE 5-6A

INITIAL POSITION AND FORECAST ERRORS (NM) FOR THE SOUTH PACIFIC AND SOUTH INDIAN OCEANS 1989 SIGNIFICANT TROPICAL CYCLONES (1 JULY 1988 - 30 JUNE 1989)

TROPICAL CYCLONE	INITIAL POSIT ERROR	24-HR FCST ERROR	24-HOUR ALONG-TRACK MEAN*	24-HOUR ALONG-TRACK MEDIAN	24-HOUR CROSS-TRACK MEAN*	24-HOUR CROSS-TRACK MEDIAN	48-HR FCST ERROR	48-HOUR ALONG-TRACK MEAN*	48-HOUR ALONG-TRACK MEDIAN	48-HOUR CROSS-TRACK MEAN*	48-HOUR CROSS-TRACK MEDIAN
TC 01S	83	235	209	**	80	**	384	349	**	134	**
TC 02S	25	98	75	-21	45	-4	169	127	-59	79	-43
TC 03S	14	106	54	**	67	**	203	122	**	125	**
TC 04P	20	74	27	**	66	**	110	80	**	76	**
TC 05P	30	130	94	**	83	**	464	408	**	222	**
TC 06S	18	100	87	**	39	**	156	113	**	99	**
TC 07S	29	141	64	**	102	**	322	170	**	244	**
TC 08S	23	105	90	**	40	**	201	166	**	81	**
TC 09S	27	162	66	**	83	**	313	116	**	193	**
TC 10P	23	111	79	-54	57	-9	269	205	-164	138	14
TC 11S	27	92	54	-39	62	34	180	119	-87	106	57
TC 12S	33	154	107	**	86	**	266	158	**	192	**
TC 13P	50	120	89	-53	59	51	207	174	**	88	**
TC 14P	34	139	80	**	94	**	238	144	**	167	**
TC 15P	22	160	123	**	87	**	390	191	**	321	**
TC 16S	35	229	219	**	69	**	***	***	***	***	***
TC 17S	13	92	32	**	86	**	332	286	**	169	**
TC 18S	40	220	182	**	55	**	400	355	**	184	**
TC 19S	25	113	58	-6	89	55	184	81	**	151	**
TC 20S	22	108	59	12	80	-24	202	134	129	123	-32
TC 21S	27	144	91	-67	101	73	282	173	-167	167	95
TC 22P	56	158	103	**	110	**	386	247	**	221	**
TC 23P	27	108	86	**	65	**	172	136	**	82	**
TC 24S	64	260	78	**	237	**	455	118	**	419	**
TC 25P	23	104	88	**	43	**	217	165	**	119	**
TC 26S	19	105	86	**	40	**	225	188	**	94	**
TC 27P	21	134	103	-31	75	-51	287	189	-152	175	-178
TC 28P	31	135	68	**	92	**	197	180	**	52	**
MEAN	31	125	85	-43	73	7	242	167	-104	137	-12
STANDARD DEVIATIONS	33	74	102	N/A	94	N/A	124	186	N/A	176	N/A

* THE MEAN WAS COMPUTED FROM ABSOLUTE VALUES.

** THE MEDIAN WAS NOT COMPUTED FOR INSTANCES OF TEN CASES OR LESS.

*** NOT ENOUGH WARNINGS WERE ISSUED TO VERIFY THE FORECAST.

SEE TABLE 5-1B FOR EXPLANATIONS OF THE TERMS MEAN, MEDIAN, ALONG-TRACK ERROR AND CROSS-TRACK ERROR.

TABLE 5-6B

NUMBER OF WARNINGS
SOUTH PACIFIC AND SOUTH INDIAN OCEANS 1989
(1 JULY 1988 - 30 JUN 1989)

TROPICAL CYCLONE	INITIAL POSITION	24-HOUR FORECAST	48-HOUR FORECAST
TC 01S ADELININA	9	8	6
TC 02S BARISAONA	26	24	22
TC 03S ILONA	11	8	6
TC 04P DELILAH	4	3	1
TC 05P GINA**	6	4	2
TC 06S - - - -	9	7	2
TC 07S EDME	11	10	8
TC 08S FIRINGA	14	10	9
TC 09S KIRRILY	9	7	5
TC 10P HARRY	24	23	21
TC 11S HANITRA	23	21	19
TC 12S GIZELA	9	7	5
TC 13P IVY	13	11	9
TC 14P - - - -**	11	9	6
TC 15P JUDY**	8	6	4
TC 16S - - - -	3	1	0
TC 17S MARCIA	3	2	1
TC 18S - - - -	4	3	1
TC 19S JINABO	13	11	3
TC 20S NED	19	15	11
TC 21S KRISSY	18	17	16
TC 22P KERRY	5	4	3
TC 23P AIVU	8	7	4
TC 24S LEZISSY	6	4	2
TC 25P LILI	9	8	8
TC 26S ORSON	12	9	7
TC 27P MEENA	16	15	12
TC 28P ERNIE	5	4	4
TC 28P ERNIE*	4	3	1
TOTALS	312	261	198

* REGENERATED
** NWOC SYSTEM

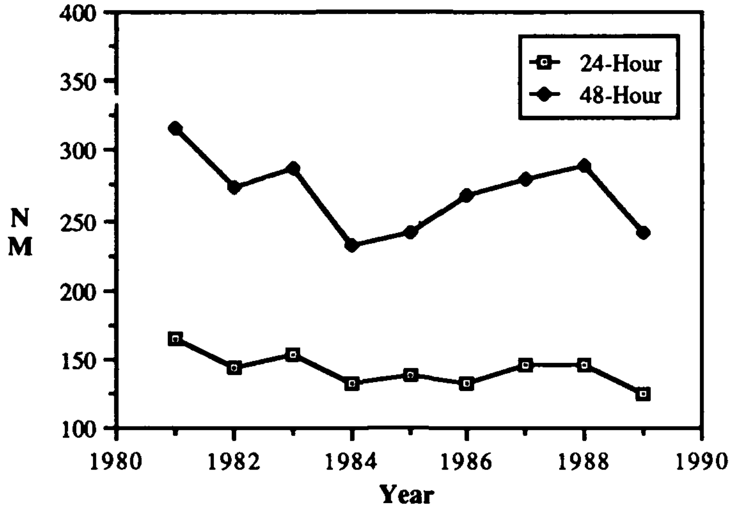


Figure 5-5. Annual mean forecast errors (nm) for all significant tropical cyclones in the South Pacific and South Indian Oceans.

TABLE 5-7

ANNUAL MEAN FORECAST ERRORS (NM)
SOUTH PACIFIC AND SOUTH INDIAN OCEANS

YEAR	24-HOUR FORECAST	24-HOUR RIGHT-ANGLE	48-HOUR FORECAST	48-HOUR RIGHT-ANGLE
1981	165	119	315	216
1982	144	91	274	174
1983	154	84	288	150
1984	133	73	231	124
1985	138	78	242	133
1986	133	**	268	**
1987	145	**	280	**
1988	146	**	290	**
1989	125	**	242	**

** IN 1986, RIGHT-ANGLE ERROR WAS REPLACED BY CROSS-TRACK ERROR. SEE TABLE 5-1B FOR AN EXPLANATION OF CROSS-TRACK ERROR.

5.2 COMPARISON OF OBJECTIVE TECHNIQUES

5.2.1 GENERAL — JTWC uses a variety of objective techniques as guidance in the warning development process. A variety of techniques are required because each technique has particular strengths and weaknesses which vary by basin, time of year, synoptic situation, and forecast period. The techniques can be divided into six general categories: extrapolation, climatology and analogs, statistical, dynamic, empirical and analytical, and blends of the previous categories.

Since September 1981, JTWC has initialized its objective forecast techniques from the six-hour old preliminary best track position (interpolated) rather than the forecast (extrapolated) warning position, e.g. the 0600Z warning is supported by objective techniques developed from the 0000Z preliminary best track position. This ensures the techniques are in-hand for a longer evaluation time and has resulted in lower 24-hour forecast errors because of more accurate direction and speed of movement.

5.2.2 DESCRIPTION OF OBJECTIVE TECHNIQUES

5.2.2.1 EXTRAPOLATION (XTRP) — Forecast positions for 24, 48, and 72 hours are derived from the extension of a straight line that connects the most recent and 12-hour old preliminary best track positions.

5.2.2.2 CLIMATOLOGY (CLIM) — A climatological aid providing 24-, 48-, and 72-hour tropical cyclone forecast positions (and intensities in the western North Pacific) based upon the position of the tropical cyclone. The output is based upon data records from 1945 to 1978 for the western North Pacific Ocean and 1900 to 1981 for the North Indian Ocean and Southern Hemisphere.

5.2.2.3 HALF PERSISTENCE AND CLIMATOLOGY (HPAC) — Forecast positions are generated from the blend of equally weighted persistence (XTRP) and climatology (CLIM) forecast positions.

5.2.2.4 ANALOGS — The program scans the climatology for tropical cyclones with a similar history (within specified spatial and temporal windows) to the current tropical cyclone. For the western North Pacific Ocean, two forecasts of position and intensity are provided at 24, 48, and 72 hours: RECR - a weighted mean of all tropical cyclones that were categorized as "recurving" during their best track period; TOTL - a weighted mean of all accepted tropical cyclones. In addition the program produces a list of the five tropical cyclones with the least variance from the current storm. For the North Indian Ocean and Southern Hemisphere, a single (total) forecast track is provided for the 24-hour intervals to 72 hours.

5.2.2.5 CLIMATOLOGY / PERSISTENCE (CLIPER) — A statistical regression technique, adapted from Xu and Neuman (1985), based on climatology, current intensity and position, and past movement. This technique is used as a crude measure of real forecast skill when verifying forecast accuracy.

5.2.2.6 CYCLOPS OBJECTIVE STEERING MODEL OUTPUT STATISTICS (COSMOS) — A Model Output Statistics (MOS) (Allen, 1982) routine based on the geostrophic steering at the 850-, 700-, and 500-mb levels. The steering is derived from the HATTRACK point advection model run using NOGAPS forecast fields. The MOS forecast is then blended with the six-hour past movement to generate the forecast track.

5.2.2.7 COLORADO STATE UNIVERSITY MODEL (CSUM) — A statistical-synoptic method developed by Matsumoto (1984). Tropical cyclones are stratified in the basins - North Indian Ocean, South China Sea, and western North Pacific - based on the tropical cyclones position relative to the 500 mb ridge

axis (determined from the direction of recent movement). A separate set of multiple regression equations using synoptic parameters are used depending on whether the tropical cyclone is south, on, or north of the ridge axis.

5.2.2.8 ONE-WAY INTERACTIVE TROPICAL CYCLONE MODEL (OTCM) — A coarse-mesh, three-layer, primitive equation model with a 205 km grid spacing over a 6400 x 4700 km domain. The model's fields are computed around a bogused, digitized cyclone vortex using FNOC analyses. The past motion of the tropical cyclone is compared to initial steering fields and a bias correction is computed and applied to the model. The resultant forecast positions are derived by locating the 850 mb vortex at six-hour intervals to 72 hours. Forecast boundary conditions are updated from NOGAPS.

5.2.2.9 TYPHOON ACCELERATION PREDICTION TECHNIQUE (TAPT) — An empirical technique (Weir, 1982) that utilizes upper-tropospheric and surface wind fields to estimate acceleration associated with the tropical cyclone's interaction with the mid-latitude westerlies. It includes guidelines for the duration of acceleration, upper-limits, and probable path of the cyclone.

5.2.2.10 COMBINED CONFIDENCE WEIGHTED FORECASTS (CCWF) — An optimal blend of objective techniques produced by the ATCF. The ATCF blends the selected techniques by using the inverse of the covariance matrices computed from historical and real-time cross-track and along-track errors as the weighting function.

5.2.2.11 DVORAK — An estimation of tropical cyclone's current and 24-hour forecast intensity is made from the interpretation of satellite imagery (Dvorak, 1984) . These intensity estimates are used with other intensity related data and trends to forecast tropical cyclone intensity.

5.2.2.12 HOLLAND/MARTIN — The technique adapts an earlier work (Holland, 1980) and specifically addresses the need for realistic 30-, 50- and 100-kt wind radii around tropical cyclones. It solves equations for basic gradient wind relations within the tropical cyclone area, using input parameters obtained from enhanced infrared satellite imagery. For the first time, diagnosis also includes an asymmetric area of winds caused by tropical cyclone movement. Size and intensity parameters are also used to diagnose internal steering components of tropical cyclone motion known collectively as "beta-drift".

5.2.2.13 FNOC BETA AND ADVECTION MODEL (FBAM) — FNOC's implementation of NMC's Beta and Advection Model. The model uses the output from NOGAPS, current observations, and an analytic description of the tropical cyclone.

5.2.2.14 NAVY OPERATIONAL REGIONAL PREDICTION SYSTEM (NRPS) — The Advanced Tropical Cyclone Model (ATCM) produced from NORAPS fields.

5.3 TESTING AND RESULTS

A comparison of selected techniques is included in Tables 5-8A, 5-8B, and 5-8C for all western North Pacific tropical cyclones; Table 5-9 for all North Indian Ocean tropical cyclones and Table 5-10 for the Southern Hemisphere. In these tables, " x-axis " refers to techniques listed vertically. For example (Table 5-8A) in the 629 cases available for a (homogeneous) comparison, the average forecast error at 24 hours was 131 nm (243 km) for HPAC and 130 nm (241 km) for COSM. The difference of 1 nm (2 km) is shown in the lower right. (Differences are not always exact, due to computational round-off which occurs for each of the cases available for comparison).

TABLE 5-8A 1989 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE WESTERN NORTH PACIFIC

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC	CLIP	OTCM	CSUM	RECR	TOTL	COSM	HPAC	CLIM	XTRP	NRPS	CCWF	FBAM
JTWC	625 120 120 0												
CLIP	587 118 119 1	683 122 122 0											
OTCM	548 114 141 27	630 118 141 23	647 141 141 0										
CSUM	526 117 119 2	591 120 120 0	575 140 117 -23	594 120 120 0									
RECR	516 116 146 30	588 117 149 32	558 140 144 4	521 117 148 31	594 149 149 0								
TOTL	534 114 126 12	605 116 131 15	576 139 127 -12	536 116 129 13	594 149 133 -16	613 131 131 0							
COSM	556 117 128 11	636 122 130 8	592 139 131 -8	573 119 127 8	551 150 127 -23	566 132 126 -6	644 137 137 0						
HPAC	583 117 128 11	673 121 131 10	626 141 127 -14	581 120 129 9	586 149 129 -20	605 131 128 -3	629 130 131 1	679 131 131 0					
CLIM	585 117 179 62	674 121 182 61	636 141 178 37	533 120 181 61	589 149 179 30	608 131 178 47	635 138 182 44	677 131 183 52	689 182 182 0				
XTRP	587 117 129 12	680 121 133 12	629 141 128 -13	588 119 129 10	588 148 128 -20	606 131 128 -3	635 130 133 3	675 131 133 2	677 183 133 -50	683 133 133 0			
NRPS	114 125 112 -13	116 127 111 -16	103 148 115 -33	104 114 115 1	104 150 109 -41	107 125 109 -16	117 131 112 -19	114 131 110 -21	115 168 111 -57	115 141 111 -30	118 111 111 0		
CCWF	378 128 128 0	449 131 129 -2	443 137 127 -10	405 129 127 -2	400 157 128 -29	407 145 127 -18	419 134 128 -6	448 139 129 -10	448 194 129 -65	449 139 129 -10	50 130 139 9	455 129 129 0	
FBAM	84 95 112 17	94 93 117 24	92 125 119 -6	90 86 118 32	80 114 125 11	85 122 119 -3	88 99 116 17	92 104 117 13	92 137 117 -20	94 106 117 11	4 174 44 -130	65 88 114 26	94 117 117 0

NUMBER OF CASES	X-AXIS TECHNIQUE ERROR
Y-AXIS TECHNIQUE ERROR	ERROR DIFFERENCE (Y-X)

CLIP - CLIMATOLOGY/PERSISENCE
OTCM - ONE-WAY TROPICAL CYCLONE MODEL
CSUM - COLORADO STATE UNIVERSITY MODEL
RECR - RECURVE ANALOG
TOTL - TOTAL ANALOG
COSM - COSMOS
HPAC - HALF PERSISTENCE AND CLIMATOLOGY
CLIM - CLIMATOLOGY
XTRP - EXTRAPOLATION
NRPS - ADVANCED TROPICAL CYCLONE MODEL
CCWF - COMBINED CONFIDENCE WEIGHTED FORECAST
FBAM - FNOC BETA AND ADVECTION MODEL

TABLE 5-8B **1989 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE WESTERN NORTH PACIFIC**

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC	CLIP	OTCM	CSUM	RECR	TOTL	COSM	HPAC	CLIM	XTRP	NRPS	CCWF	FBAM
JTWC	481 231 231 0												
CLIP	461 227 252 25	575 264 264 0											
OTCM	431 224 288 64	529 257 284 27	546 284 284 0										
CSUM	416 226 250 24	494 263 250 -13	477 283 241 -42	498 251 251 0									
RECR	409 226 307 81	491 252 318 66	465 286 315 29	431 247 320 73	498 318 318 0								
TOTL	422 223 245 22	508 250 265 15	483 284 260 -24	445 243 262 19	498 318 271 -47	517 265 265 0							
COSM	436 223 255 32	533 267 267 0	497 281 269 -12	482 249 262 13	461 319 264 -55	475 264 263 -1	542 274 274 0						
HPAC	458 226 241 15	566 261 253 -8	528 284 250 -34	486 249 249 0	490 319 254 -65	509 265 251 -14	528 265 253 -12	573 254 254 0					
CLIM	461 227 316 89	568 261 331 70	538 284 329 45	489 250 333 83	493 319 335 16	512 265 334 69	535 273 331 58	572 254 332 78	584 332 332 0				
XTRP	462 225 276 51	573 263 291 28	531 285 283 -2	493 249 283 34	492 318 283 -35	510 265 282 17	534 267 291 24	570 254 292 38	572 333 291 -42	577 290 290 0			
NRPS	66 193 229 36	72 241 220 -21	59 311 220 -91	65 217 227 10	65 300 216 -84	68 233 216 -17	73 245 220 -25	71 244 217 -27	72 311 217 -94	72 276 220 -56	73 220 220 0		
CCWF	316 248 475 227	399 283 478 195	391 272 490 218	358 266 305 39	351 333 520 187	359 287 510 223	370 278 284 6	399 264 485 221	399 349 484 135	400 305 477 172	20 201 246 45	406 485 485 0	
FBAM	70 177 250 73	82 202 253 51	80 317 257 -60	78 143 255 112	68 285 274 -11	73 237 263 26	77 222 255 33	80 187 255 68	80 225 255 30	82 225 255 30	4 343 98 -245	62 413 270 -143	82 253 253 0

NUMBER OF CASES	X-AXIS TECHNIQUE ERROR
Y-AXIS TECHNIQUE ERROR	ERROR DIFFERENCE (Y-X)

CLIP - CLIMATOLOGY/PERSISENCE
OTCM - ONE-WAY TROPICAL CYCLONE MODEL
CSUM - COLORADO STATE UNIVERSITY MODEL
RECR - RECURVE ANALOG
TOTL - TOTAL ANALOG
COSM - COSMOS
HPAC - HALF PERSISTENCE AND CLIMATOLOGY
CLIM - CLIMATOLOGY
XTRP - EXTRAPOLATION
NRPS - ADVANCED TROPICAL CYCLONE MODEL
CCWF - COMBINED CONFIDENCE WEIGHTED FORECAST
FBAM - FNOC BETA AND ADVECTION MODEL

TABLE 5-8C 1989 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE WESTERN NORTH PACIFIC

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC	CLIP	OTCM	CSUM	RECR	TOTL	COSM	HPAC	CLIM	XTRP	NRPS	CCWF	NRPS
JTWC	363 350												
	350 0												
CLIP	347 346	458 402											
	371 25	402 0											
OTCM	307 339	397 390	411 446										
	459 120	449 59	446 0										
CSUM	313 334	393 402	354 448	395 370									
	365 31	370 -32	361 -87	370 0									
RECR	309 348	389 383	348 452	341 362	395 496								
	479 131	495 112	502 50	503 141	496 0								
TOTL	315 348	396 384	355 454	347 361	395 496	404 422							
	395 47	421 37	412 -42	416 55	424 -72	422 0							
COSM	328 337	421 403	373 440	382 369	361 492	368 411	430 424						
	401 64	427 24	415 -25	428 59	415 -77	417 6	424 0						
HPAC	335 348	440 393	387 449	376 370	387 499	396 422	407 419	446 381					
	363 15	380 -13	377 -72	376 6	376 -123	374 -48	377 -42	381 0					
CLIM	338 347	442 393	398 445	378 370	391 498	400 422	414 418	446 381	457 451				
	434 87	451 58	452 7	460 90	461 -37	461 39	453 35	453 72	451 0				
XTRP	350 345	457 401	398 449	393 370	390 497	398 422	422 426	444 381	446 453	461 454			
	434 89	455 54	445 -4	443 73	440 -57	440 18	449 23	460 79	458 5	454 0			
NRPS	49 307	55 358	44 537	51 299	52 516	52 377	57 368	53 385	54 485	56 406	57 410		
	440 133	413 55	430 -107	430 131	403 -113	403 26	410 42	401 16	397 -88	413 7	410 0		
CCWF	238 359	319 406	292 406	281 372	282 494	288 433	290 419	317 376	318 455	320 466	15 358	324 395	
	377 18	393 -13	391 -15	386 14	381 -113	380 -53	382 -37	394 18	394 -61	393 -73	403 45	395 0	
FBAM	59 265	71 327	62 526	68 193	55 419	57 389	66 473	62 276	62 303	71 353	3 632	55 386	71 408
	416 151	408 81	379 -147	409 216	432 13	442 53	409 -64	432 156	432 129	408 55	150 -482	450 64	408 0

NUMBER OF CASES	X-AXIS TECHNIQUE ERROR
Y-AXIS TECHNIQUE ERROR	ERROR DIFFERENCE (Y-X)

CLIP - CLIMATOLOGY/PERSISENCE
OTCM - ONE-WAY TROPICAL CYCLONE MODEL
CSUM - COLORADO STATE UNIVERSITY MODEL
RECR - RECURVE ANALOG
TOTL - TOTAL ANALOG
COSM - COSMOS
HPAC - HALF PERSISTENCE AND CLIMATOLOGY
CLIM - CLIMATOLOGY
XTRP - EXTRAPOLATION
NRPS - ADVANCED TROPICAL CYCLONE MODEL
CCWF - COMBINED CONFIDENCE WEIGHTED FORECAST
FBAM - FNOC BETA AND ADVECTION MODEL

TABLE 5-9 1989 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTH INDIAN OCEAN

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	CSUM	HPAC	CLIM	XTRP	CCWF	FBAM
JTWC	33 88 88 0							
OTCM	33 88 110 22	36 116 116 0						
CSUM	33 88 105 17	36 116 113 -3	36 113 113 0					
HPAC	32 85 100 15	35 115 102 -13	35 111 102 -9	35 102 102 0				
CLIM	32 85 159 74	35 115 159 44	35 111 159 48	35 102 159 57	35 159 159 0			
XTRP	32 85 70 -15	35 115 76 -39	35 111 76 -35	35 102 76 -26	35 159 76 -83	35 76 76 0		
CCWF	5 118 93 -25	7 121 111 -10	7 124 111 -13	7 110 111 1	7 134 111 -23	7 107 111 4	7 111 111 0	
FBAM	21 76 75 -1	21 119 75 -44	21 68 75 7	21 114 75 -39	21 191 75 -116	21 62 75 13	0 0 0 0	21 75 75 0

NUMBER OF CASES	X-AXIS TECHNIQUE ERROR
Y-AXIS TECHINQUE ERROR	ERROR DIFFERENCE (Y-X)

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	CSUM	HPAC	CLIM	XTRP	CCWF	FBAM
JTWC	17 146 146 0							
OTCM	17 146 335 189	25 304 304 0						
CSUM	17 146 136 -10	25 304 199 -105	26 194 194 0					
HPAC	17 146 224 78	24 307 205 -102	25 191 199 8	25 199 199 0				
CLIM	17 146 379 233	24 307 305 -2	25 191 296 105	25 199 296 97	25 296 296 0			
XTRP	17 146 120 -26	24 307 151 -156	25 191 146 -45	25 199 146 -53	25 296 146 -150	25 146 146 0		
CCWF	0 0 0 0	6 240 202 -38	7 290 179 -111	7 147 179 32	7 121 179 58	7 202 179 -23	7 179 179 0	
FBAM	17 146 167 21	17 335 167 -168	17 136 167 31	17 224 167 -57	17 379 167 -212	17 120 167 47	0 0 0 0	17 167 167 0

JTWC - OFFICIAL JTWC FORECAST
OTCM - ONE-WAY TROPICAL CYCLONE MODEL
HPAC - HALF PERSISTENCE AND CLIMATOLOGY BLEND
CLIM - CLIMATOLOGY
XTRP - 12-HOUR EXTRAPOLATION
CCWF - COMBINED CONFIDENCE WEIGHTED FORECAST
FBAM - FNOC BETA AND ADVECTION MODEL

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	CSUM	HPAC	CLIM	XTRP	CCWF	FBAM
JTWC	12 216 216 0							
OTCM	12 216 492 276	18 463 463 0						
CSUM	12 216 206 -10	18 463 291 -172	18 291 291 0					
HPAC	11 210 237 27	16 474 246 -228	16 291 246 -45	16 246 246 0				
CLIM	11 210 387 177	16 474 343 -131	16 291 343 52	16 246 343 97	16 343 343 0			
XTRP	12 216 152 -64	17 473 203 -270	17 284 203 -81	16 246 195 -51	16 343 195 -148	17 203 203 0		
CCWF	0 0 0 0	4 373 333 -40	4 511 333 -178	4 250 333 83	4 163 333 170	4 388 333 -55	4 333 333 0	
FBAM	12 216 262 46	13 504 274 -230	13 214 274 60	12 245 281 36	12 403 281 -122	13 146 274 128	0 0 0 0	13 274 274 0

TABLE 5-10 **1989 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE SOUTHERN HEMISPHERE 1989 (1 JULY 1988 - 30 JUNE 1989)**

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC		CLIP		OTCM		HPAC		CLIM		XTRP		CCWF	
JTWC	261	125												
	125	0												
CLIP	90	124	217	152										
	144	20	152	0										
OTCM	200	119	145	147	381	123								
	126	7	128	-19	123	0								
HPAC	195	117	145	146	369	123	377	116						
	117	0	111	-35	116	-7	116	0						
CLIM	197	117	145	146	373	124	375	116	381	171				
	160	43	153	7	172	48	171	55	171	0				
XTRP	196	118	142	146	368	123	372	116	373	172	376	123		
	126	8	120	-26	123	0	123	7	123	-49	123	0		
CCWF	78	110	73	152	151	107	151	109	151	153	150	107	151	101
	101	-9	96	-56	101	-6	101	-8	101	-52	101	-6	101	0

NUMBER OF CASES	X-AXIS TECHNIQUE ERROR
Y-AXIS TECHINQUE ERROR	ERROR DIFFERENCE (Y-X)

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC		CLIP		OTCM		HPAC		CLIM		XTRP		CCWF	
JTWC	201	242												
	242	0												
CLIP	66	230	180	334										
	296	66	334	0										
OTCM	152	233	114	307	309	239								
	235	2	230	-77	239	0								
HPAC	148	233	115	304	292	237	305	223						
	229	-4	205	-99	219	-18	223	0						
CLIM	150	235	115	305	296	238	303	224	309	301				
	295	60	248	-57	294	56	300	76	301	0				
XTRP	152	232	112	303	296	237	300	224	301	303	309	257		
	260	28	250	-53	258	21	257	33	258	-45	257	0		
CCWF	67	236	61	306	134	207	134	218	134	275	133	244	134	193
	197	-39	169	-137	193	-14	193	-25	193	-82	193	-51	193	0

JTWC - OFFICIAL JTWC FORECAST
CLIP - CLIPER (CLIMATOLOGY AND PERSISTENCE)
OTCM - ONE-WAY TROPICAL CYCLONE MODEL
HPAC - HALF PERSISTENCE AND CLIMATOLOGY BLEND
CLIM - CLIMATOLOGY
XTRP - 12-HOUR EXTRAPOLATION
CCWF - COMBINED CONFIDENCE WEIGHTED FORECAST

72-HOUR MEAN FORECAST ERROR (NM)

	OTCM		HPAC		CLIM		XTRP		CCWF	
OTCM	222	350								
	350	0								
HPAC	209	352	238	336						
	309	-43	336	0						
CLIM	212	354	237	337	241	426				
	385	31	427	90	426	0				
XTRP	212	343	234	337	234	430	241	388		
	382	39	392	55	392	-38	388	0		
CCWF	95	309	96	304	96	342	95	374	96	455
	406	97	455	151	455	113	455	81	455	0

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6. NOARL TROPICAL CYCLONE SUPPORT SUMMARY

Tropical Cyclone Forecaster's Reference Guide

R. J. Miller and J-H. Chu

Development of a Tropical Cyclone Forecaster's Reference Guide has started at Naval Oceanographic and Atmospheric Research Laboratory (NOARL). The reference guide will be a computer-based information management system for JTWC forecasters. Using a mouse/menu interface, the user will have access to general tropical cyclone information, as well as current research results, thumb rules, definitions, case studies, etc. Since the guide will be computer-based, one can easily add new information to the system, or modify existing information.

Automated Tropical Cyclone Forecasting System (ATCF) Upgrade

D. M. Roesser, C. R. Sampson, and R. J. Miller

The ATCF has been operational at JTWC since August, 1988. The system runs on an IBM-AT compatible machine using the MS-DOS operation system. This current configuration limits the capabilities of the ATCF. For this reason, work is underway to adapt the ATCF software to a UNIX environment. The UNIX operating system runs more powerful applications and is capable of multitasking (running more than one program at once). Additionally, software developed for UNIX is portable to a wide variety of computer systems (personal computers, workstations, or mainframes).

Tropical Cyclone Expert System

C. R. Sampson and J-H. Chu

NOARL is developing an expert system for tropical cyclone forecasting. Using forecasting thumb rules and research results such as objective technique error statistics, the expert system will objectively weigh the information based upon the current forecast situation and assist the forecaster in making decisions. More importantly, the expert system may alert the forecaster to possibilities not previously considered.

Personal Computer-Based Track Climatology

C. R. Sampson and R. J. Miller

Currently the Fleet Numerical Oceanography Center (FNOC) in Monterey, CA runs all of JTWC's computer objective forecast techniques on the mainframe computers. With the increased power and use of personal computers, it is now feasible to run some of these forecast techniques locally at JTWC. NOARL is adapting the tropical cyclone track climatology forecast technique to run on a PC. The global data base contains best tracks since 1945 to present. At the end of each tropical cyclone season, new best tracks can easily be added to the data base.

NORAPS/ATCM Development

C-S. Liou

Since the Advanced Tropical Cyclone Model (ATCM) is a special application of the Navy Operational Regional Atmospheric Prediction System (NORAPS), any changes made to NORAPS will also affect ATCM performance. In 1989-1990, NORAPS development efforts are focused on improving lateral boundary conditions, radiation calculation, and initialization procedures. The improvements are aimed at reducing forecast errors due to ill-posed lateral boundary conditions, to reduce large bias errors, and to reduce errors due to vertical interpolation between sigma and pressure levels.

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7. TROPICAL CYCLONE WARNING STATISTICS, TRACK AND FIX DATA

7.1 GENERAL

Due to the rapid growth of micro-computers in the meteorological community and to save publishing costs, tropical cyclone track data (with best track, initial warning, 24-, 48- and 72-hour JTWC forecasts) and fix data (satellite, aircraft, radar and synoptic) are now available separately upon request. The data will be in ASCII format on 5.25 inch floppy diskettes. The data sets are available on two diskettes. These include the western North Pacific Ocean (1 January - 31 December 1989) on one and North Indian Ocean (1 January - 31 December), South Indian and western South Pacific Oceans (1 July 1988 - 30 June 1989) on the other. Agencies or individuals desiring these data sets should send the appropriate number of floppy diskettes (two if both data sets are desired) to NAVOCEANCOMCEN/JTWC Guam with their request. When the request is received, the data will be copied onto your diskettes and returned with the explanation of the data formats. The use of floppy diskettes should facilitate the transfer of these rather large data files to your computer.

7.2 WARNING VERIFICATION STATISTICS

7.2.1 WESTERN NORTH PACIFIC

This section includes verification statistics for each warning in the western North Pacific Ocean during 1989. Pre- and post-warning best track positions are not printed, but are available on floppy diskettes by request.

JTWC FORECAST TRACK AND INTENSITY ERRORS BY WARNING

Tropical Storm Winona (01W)

	00h	24h	48h	72h
Average	25	171	346	507
# Cases	13	10	6	5

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WN ER	24 ER	48 ER	72 ER
89011800	1	16.5N	153.8E	16	63	225	304	40	-5	-10	15	35
89011806	2	16.4N	151.8E	5	100	314	318	45	-10	-10	25	40
89011812	3	16.2N	150.0E	18	265	527	674	50	0	5	35	45
89011818	4	15.8N	148.0E	37	279	482	718	50	0	15	35	50
89011900	5	15.2N	145.7E	8	181	254	521	55	0	25	40	45
89011906	6	14.6N	142.9E	11	177	271	N\A	55	0	35	45	N\A
89011912	7	14.0N	140.0E	18	108	N\A	N\A	55	-10	0	N\A	N\A
89011918	8	13.8N	137.2E	25	N\A	N\A	N\A	45	-5	N\A	N\A	N\A
89012006*	9	13.5N	132.3E	5	169	N\A	N\A	30	0	20	N\A	N\A
89012012	10	13.5N	130.5E	24	196	N\A	N\A	30	0	20	N\A	N\A
89012018	11	13.3N	128.9E	65	176	N\A	N\A	30	0	10	N\A	N\A
89012100	12	13.1N	127.7E	37	N\A	N\A	N\A	30	0	N\A	N\A	N\A
89012106	13	12.3N	126.3E	51	N\A	N\A	N\A	25	0	N\A	N\A	N\A

* Regenerated

Super Typhoon Andy (02W)

	00h	24h	48h	72h
Average	12	111	290	569
# Cases	26	26	22	18

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WN ER	24 ER	48 ER	72 ER
89041718	1	8.1N	147.0E	51	125	254	605	35	-5	-15	-30	-80
89041800	2	8.7N	146.4E	18	18	101	346	40	5	10	5	-65
89041806	3	9.2N	145.9E	13	157	216	413	45	0	15	-10	-75

Super Typhoon Andy (02W) (continued)

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89041812	4	9.6N	145.3E	8	126	291	664	45	5	-5	-45	-75
89041818	5	9.7N	144.5E	11	164	463	872	50	-5	-20	-70	-60
89041900	6	9.7N	143.9E	13	65	317	692	55	0	-10	-50	-65
89041906	7	9.7N	143.5E	21	165	475	857	60	-15	-45	-80	-60
89041912	8	9.9N	143.3E	8	181	559	960	70	-5	-45	-50	-20
89041918	9	10.1N	143.3E	0	89	357	617	75	0	-45	-45	-15
89042000	10	10.5N	143.5E	21	148	372	533	85	-5	-50	-45	-5
89042006	11	10.9N	143.8E	11	196	473	653	100	-5	-25	-5	35
89042012	12	11.5N	144.1E	6	242	479	614	120	5	5	35	85
89042018	13	12.0N	145.0E	0	125	267	343	135	-5	-25	0	55
89042100	14	12.6N	145.9E	5	162	307	384	140	-5	10	45	70
89042106	15	13.4N	146.9E	5	84	192	402	140	-5	-5	25	35
89042112	16	14.2N	148.2E	0	121	245	449	140	-10	0	40	30
89042118	17	15.4N	149.4E	18	66	280	509	135	-5	0	50	30
89042200	18	16.4N	150.5E	5	62	164	330	130	-10	15	35	10
89042206	19	17.4N	151.5E	8	41	168	N/A	120	-10	10	25	N/A
89042212	20	18.5N	152.5E	6	90	175	N/A	110	0	40	35	N/A
89042218	21	19.6N	153.4E	18	85	128	N/A	100	0	40	25	N/A
89042300	22	20.8N	154.3E	16	100	96	N/A	85	5	25	15	N/A
89042306	23	21.6N	155.1E	12	17	N/A	N/A	65	10	15	N/A	N/A
89042312	24	22.5N	155.6E	12	44	N/A	N/A	45	15	15	N/A	N/A
89042318	25	23.4N	156.1E	17	128	N/A	N/A	35	15	5	N/A	N/A
89042400	26	24.4N	156.7E	16	95	N/A	N/A	30	5	5	N/A	N/A

Typhoon Brenda (03W)

	00h	24h	48h	72h
Average	31	133	227	251
# Cases	20	18	12	9

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89051518	1	9.8N	130.2E	95	283	406	411	30	-5	0	30	25
89051600	2	10.4N	129.1E	147	268	339	268	30	5	5	20	20
89051606	3	11.0N	128.0E	36	190	261	223	35	10	15	15	15
89051612	4	11.7N	126.6E	81	247	306	329	40	10	5	5	0
89051618	5	12.3N	125.2E	26	156	203	247	45	0	0	-10	-15
89051700	6	12.8N	123.8E	40	90	60	82	50	5	25	15	-20
89051706	7	13.4N	122.6E	18	106	130	252	50	0	15	20	-15
89051712	8	13.9N	121.4E	13	21	57	247	40	5	10	10	-5
89051718	9	14.5N	120.5E	18	45	54	202	35	0	-5	-10	-10
89051800	10	15.2N	119.6E	11	51	92	N/A	35	5	0	-5	N/A
89051806	11	15.8N	118.8E	29	174	N/A	N/A	45	0	10	N/A	N/A
89051812	12	16.5N	118.2E	8	73	228	N/A	45	0	-10	-40	N/A
89051818	13	17.1N	117.7E	16	84	N/A	N/A	50	-5	-20	N/A	N/A
89051900	14	17.7N	117.2E	18	213	584	N/A	55	-5	-35	0	N/A
89051906	15	18.4N	116.7E	11	102	N/A	N/A	55	0	-5	N/A	N/A
89051912	16	19.1N	116.0E	12	86	N/A	N/A	65	0	-5	N/A	N/A
89051918	17	19.8N	115.2E	25	90	N/A	N/A	75	-10	15	N/A	N/A
89052000	18	20.5N	114.4E	5	105	N/A	N/A	75	0	0	N/A	N/A
89052006	19	21.1N	113.8E	6	N/A	N/A	N/A	70	5	N/A	N/A	N/A
89052012	20	21.6N	113.1E	5	N/A	N/A	N/A	70	0	N/A	N/A	N/A

Typhoon Cecil (04W)

	00h	24h	48h	72h
Average	19	127	358	N/A
# Cases	9	8	5	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89052218	1	13.6N	113.0E	50	120	329	N/A	45	0	0	-20	N/A
89052300	2	14.3N	112.6E	13	177	429	N/A	50	0	0	0	N/A
89052306	3	14.8N	112.1E	21	166	322	N/A	55	0	0	25	N/A

Typhoon Cecil (04W) (continued)

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89052312	4	15.2N	111.5E	21	154	338	N/A	55	0	-5	20	N/A
89052318	5	15.5N	111.0E	21	190	374	N/A	60	-5	0	20	N/A
89052400	6	15.7N	110.4E	13	120	N/A	N/A	65	-10	10	N/A	N/A
89052406	7	15.7N	109.7E	11	30	N/A	N/A	70	-5	30	N/A	N/A
89052412	8	15.8N	109.2E	18	58	N/A	N/A	75	0	35	N/A	N/A
89052418	9	15.8N	108.6E	6	N/A	N/A	N/A	70	-5	N/A	N/A	N/A

Typhoon Dot (05W)

	00h	24h	48h	72h
Average	16	78	148	163
# Cases	25	23	17	11

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89060500	1	9.8N	130.7E	17	95	216	236	30	-5	15	10	-10
89060506	2	10.2N	129.3E	34	79	187	161	30	0	20	-5	-25
89060512	3	10.5N	127.9E	18	21	24	59	35	-5	-10	-10	-35
89060518	4	11.0N	126.7E	13	39	41	91	35	0	-15	-10	-40
89060600	5	11.4N	125.7E	26	169	191	180	40	5	0	-20	-40
89060606	6	11.8N	124.5E	35	157	138	98	40	5	-5	-5	-30
89060612	7	12.2N	123.1E	17	42	47	81	45	5	5	-20	-25
89060618	8	12.6N	121.5E	8	47	107	173	50	5	15	-15	-30
89060700	9	13.1N	120.1E	21	120	192	260	50	0	10	-20	-35
89060706	10	13.6N	119.1E	8	53	153	204	55	0	5	-20	-40
89060712	11	14.3N	118.4E	6	82	221	252	55	0	-10	-25	-30
89060718	12	14.9N	117.6E	12	103	252	N/A	55	0	-20	-40	N/A
89060800	13	15.3N	116.7E	13	87	164	N/A	60	-5	-25	-45	N/A
89060806	14	15.7N	115.9E	8	91	203	N/A	65	0	-10	-45	N/A
89060812	15	16.1N	115.1E	17	180	N/A	N/A	85	-20	-5	N/A	N/A
89060818	16	16.4N	114.4E	18	103	N/A	N/A	95	-5	5	N/A	N/A
89060900	17	16.6N	113.6E	5	61	158	N/A	100	0	5	25	N/A
89060906	18	16.9N	112.8E	18	36	132	N/A	100	0	-10	10	N/A
89060912	19	17.2N	111.9E	6	37	84	N/A	95	0	25	35	N/A
89060918	20	17.6N	111.1E	6	41	N/A	N/A	95	0	25	N/A	N/A
89061000	21	18.1N	110.2E	12	70	N/A	N/A	95	-5	-5	N/A	N/A
89061006	22	18.6N	109.2E	13	29	N/A	N/A	80	-15	-15	N/A	N/A
89061012	23	19.0N	108.2E	11	47	N/A	N/A	60	-5	0	N/A	N/A
89061018	24	19.4N	107.3E	21	N/A	N/A	N/A	55	-10	N/A	N/A	N/A
89061100	25	20.2N	106.5E	48	N/A	N/A	N/A	55	-10	N/A	N/A	N/A

Tropical Storm Ellis (06W)

	00h	24h	48h	72h
Average	33	347	N/A	N/A
# Cases	6	6	0	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89062006†	1	16.4N	128.9E	24	240	N/A	N/A	25	0	5	N/A	N/A
89062018†	2	17.3N	127.4E	65	266	N/A	N/A	25	0	5	N/A	N/A
89062218*	3	20.0N	126.1E	11	463	N/A	N/A	30	0	0	N/A	N/A
89062300	4	21.0N	126.8E	42	653	N/A	N/A	35	0	0	N/A	N/A
89062306	5	23.2N	127.9E	36	336	N/A	N/A	35	0	-5	N/A	N/A
89062312	6	25.4N	128.8E	18	125	N/A	N/A	35	-5	-10	N/A	N/A

† Tropical Depression Warning
* Regenerated

Tropical Storm Faye (07W)

	00h	24h	48h	72h
Average	25	72	124	220
# Cases	21	18	12	10

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WN ER	24 ER	48 ER	72 ER
89070606	1	15.4N	129.6E	13	72	33	114	25	0	0	10	-10
89070612	2	15.9N	129.2E	43	75	42	150	25	5	-5	-5	-5
89070618	3	16.3N	128.7E	74	90	83	194	25	0	-10	10	0
89070700	4	16.7N	128.1E	60	59	185	310	30	0	-5	5	10
89070706	5	16.9N	127.4E	18	53	207	280	35	0	-5	0	20
89070712	6	17.0N	126.5E	24	81	169	248	35	0	-5	10	40
89070718	7	17.0N	125.7E	16	74	124	160	40	-5	15	25	40
89070800	8	16.7N	124.6E	11	77	183	257	45	0	10	35	60
89070806	9	16.7N	123.5E	24	55	124	230	55	0	20	40	50
89070812	10	16.9N	122.4E	30	82	166	257	60	0	20	40	45
89070818	11	17.2N	120.8E	62	69	135	N/A	40	0	25	45	N/A
89070900	12	17.3N	119.1E	11	41	32	N/A	45	0	35	30	N/A
89070906	13	17.5N	117.6E	17	62	N/A	N/A	45	0	-5	N/A	N/A
89070912	14	17.7N	116.5E	29	146	N/A	N/A	45	-5	-5	N/A	N/A
89070918	15	18.2N	115.4E	43	135	N/A	N/A	40	0	0	N/A	N/A
89071000	16	18.7N	114.0E	13	17	N/A	N/A	40	0	-5	N/A	N/A
89071006	17	19.1N	112.7E	5	88	N/A	N/A	35	0	-10	N/A	N/A
89071012	18	19.5N	111.4E	8	25	N/A	N/A	35	0	0	N/A	N/A
89071018	19	20.0N	110.3E	6	N/A	N/A	N/A	30	5	N/A	N/A	N/A
89071100	20	20.5N	109.1E	17	N/A	N/A	N/A	30	0	N/A	N/A	N/A
89071106	21	21.2N	107.7E	0	N/A	N/A	N/A	30	0	N/A	N/A	N/A

Super Typhoon Gordon (08W)

	00h	24h	48h	72h
Average	13	68	118	146
# Cases	30	26	24	18

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WN ER	24 ER	48 ER	72 ER
89071106	1	18.6N	147.3E	72	33	80	120	30	0	-10	-15	-35
89071112	2	18.5N	145.3E	13	30	70	138	30	0	-5	-10	-35
89071118	3	18.3N	144.0E	24	23	93	121	30	0	-10	-15	-50
89071200	4	18.1N	142.6E	22	8	90	96	35	-5	-10	-20	-65
89071206	5	18.0N	141.3E	12	53	123	105	40	5	5	-15	-50
89071212	6	17.9N	139.9E	0	62	98	55	45	0	0	-25	-50
89071218	7	17.9N	138.3E	8	72	96	47	50	-5	-5	-40	-55
89071300	8	17.8N	136.7E	12	124	179	214	55	0	-10	-50	-35
89071306	9	17.6N	135.1E	8	117	149	192	60	5	0	-40	-20
89071312	10	17.0N	133.8E	12	85	183	284	65	5	-5	-65	-10
89071318	11	16.5N	132.6E	5	25	116	165	70	-5	-40	-75	-15
89071400	12	16.4N	131.4E	6	5	67	142	75	0	-35	-55	0
89071406	13	16.3N	130.2E	8	49	157	188	90	-5	-30	-35	10
89071412	14	16.3N	128.8E	5	104	136	172	100	10	-15	-15	15
89071418	15	16.4N	127.4E	13	119	112	152	115	-5	-60	-5	20
89071500	16	16.6N	126.2E	12	132	151	185	125	0	-40	10	25
89071506	17	17.0N	125.1E	13	116	130	110	140	-5	-30	15	-5
89071512	18	17.5N	124.0E	12	30	20	143	140	-5	-5	30	-5
89071518	19	17.9N	122.6E	13	97	98	N/A	140	-5	20	25	N/A
89071600	20	18.2N	121.3E	13	111	94	N/A	120	-25	10	15	N/A
89071606	21	18.3N	120.1E	5	34	98	N/A	110	-30	20	-25	N/A
89071612	22	18.5N	118.8E	6	33	116	N/A	100	-15	30	-20	N/A
89071618	23	18.6N	117.6E	12	83	250	N/A	90	0	35	-10	N/A
89071700	24	19.1N	116.6E	16	26	126	N/A	80	0	30	5	N/A
89071706	25	19.7N	115.6E	8	81	N/A	N/A	75	0	-5	N/A	N/A
89071712	26	20.4N	114.7E	6	115	N/A	N/A	70	0	-20	N/A	N/A
89071718	27	20.8N	113.6E	12	N/A	N/A	N/A	65	0	N/A	N/A	N/A
89071800	28	21.1N	112.5E	18	N/A	N/A	N/A	60	0	N/A	N/A	N/A
89071806	29	21.4N	111.3E	16	N/A	N/A	N/A	55	0	N/A	N/A	N/A
89071812	30	21.7N	110.0E	5	N/A	N/A	N/A	50	-5	N/A	N/A	N/A

Tropical Storm Hope (09W)

	00h	24h	48h	72h
Average	21	112	224	309
# Cases	21	17	14	5

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89071600	1	20.8N	134.8E	103	194	273	398	30	-5	0	0	-20
89071606	2	21.0N	134.0E	18	98	158	257	30	0	0	15	-15
89071612	3	21.1N	133.0E	16	111	212	324	30	5	0	15	-30
89071618	4	21.5N	131.8E	24	167	248	277	35	0	5	-10	-30
89071700	5	22.2N	130.8E	42	137	208	29	35	5	15	-15	-30
89071706	6	23.0N	130.0E	0	91	150	N/A	40	-5	-15	-10	N/A
89071712	7	23.6N	128.8E	21	134	175	N/A	40	-5	-10	-25	N/A
89071718	8	24.2N	127.9E	10	129	287	N/A	45	-5	-5	-25	N/A
89071800	9	24.5N	127.0E	0	89	235	N/A	45	0	10	-25	N/A
89071806	10	24.9N	126.4E	13	32	171	N/A	50	0	15	-15	N/A
89071812	11	25.3N	125.8E	12	60	146	N/A	50	0	15	-5	N/A
89071818	12	25.8N	125.2E	18	54	207	N/A	55	-5	0	20	N/A
89071900	13	26.6N	124.6E	16	86	276	N/A	55	0	-5	15	N/A
89071906	14	27.2N	124.1E	21	112	383	N/A	55	0	0	15	N/A
89071912	15	27.8N	123.7E	5	72	N/A	N/A	55	-10	0	N/A	N/A
89071918	16	28.4N	123.3E	16	150	N/A	N/A	55	-10	0	N/A	N/A
89072000	17	28.6N	122.9E	43	181	N/A	N/A	55	-10	0	N/A	N/A
89072006	18	28.7N	122.5E	31	N/A	N/A	N/A	45	-5	N/A	N/A	N/A
89072012	19	28.8N	122.0E	23	N/A	N/A	N/A	35	0	N/A	N/A	N/A
89072018	20	28.9N	121.5E	6	N/A	N/A	N/A	30	0	N/A	N/A	N/A
89072100	21	29.0N	121.1E	0	N/A	N/A	N/A	30	0	N/A	N/A	N/A

Tropical Storm Irving (10W)

	00h	24h	48h	72h
Average	21	90	152	232
# Cases	14	9	4	2

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89072100	1	15.0N	116.7E	21	174	264	389	30	-5	0	5	5
89072106	2	15.1N	115.0E	17	8	29	74	35	0	10	15	5
89072112	3	15.0N	113.4E	30	163	254	N/A	40	0	20	-20	N/A
89072118	4	15.0N	112.2E	29	166	N/A	N/A	40	5	0	N/A	N/A
89072200	5	15.5N	111.3E	8	56	N/A	N/A	40	5	-10	N/A	N/A
89072206	6	16.4N	110.7E	40	49	62	N/A	40	-5	-10	-10	N/A
89072212	7	16.7N	110.2E	20	49	N/A	N/A	40	-5	-10	N/A	N/A
89072218	8	16.8N	109.5E	24	47	N/A	N/A	40	-5	-20	N/A	N/A
89072300	9	17.1N	108.6E	25	101	N/A	N/A	45	-10	-30	N/A	N/A
89072306	10	17.5N	107.7E	8	N/A	N/A	N/A	45	-15	N/A	N/A	N/A
89072312	11	18.1N	107.0E	16	N/A	N/A	N/A	45	-15	N/A	N/A	N/A
89072318	12	18.6N	106.3E	36	N/A	N/A	N/A	55	-30	N/A	N/A	N/A
89072400	13	19.2N	105.7E	18	N/A	N/A	N/A	55	-20	N/A	N/A	N/A
89072406	14	19.7N	104.9E	0	N/A	N/A	N/A	40	-10	N/A	N/A	N/A

Typhoon Judy (11W)

	00h	24h	48h	72h
Average	15	85	195	323
# Cases	28	24	20	16

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89072206	1	14.8N	138.8E	18	119	290	446	25	0	5	0	-20
89072212	2	15.4N	138.3E	52	67	39	106	25	0	0	-10	-40
89072218	3	16.1N	138.0E	31	23	24	136	30	-5	-5	-25	-45
89072300	4	16.5N	138.0E	26	60	43	85	35	0	0	-25	-35
89072306	5	17.0N	138.0E	32	30	24	139	35	0	-5	-35	-30
89072312	6	17.5N	138.0E	13	90	174	277	35	0	-5	-35	-15
89072318	7	18.2N	138.1E	30	87	180	296	35	5	-10	-30	-15
89072400	8	18.9N	138.2E	6	84	95	241	50	0	-10	0	25

Typhoon Judy (11W) (continued)

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89072406	9	19.6N	138.3E	13	42	125	308	55	0	-15	10	25
89072412	10	20.2N	138.4E	11	48	103	272	55	0	-20	10	0
89072418	11	20.9N	138.4E	11	55	111	316	65	0	-10	10	0
89072500	12	21.8N	138.4E	11	41	146	389	80	0	10	30	30
89072506	13	22.8N	138.3E	8	69	274	485	90	0	20	30	40
89072512	14	23.9N	138.0E	10	87	376	652	95	0	25	30	40
89072518	15	24.9N	137.9E	5	123	383	578	95	0	25	5	25
89072600	16	26.0N	137.5E	8	150	388	437	90	0	5	10	30
89072606	17	26.8N	136.9E	0	155	375	N/A	90	0	0	0	N/A
89072612	18	27.6N	136.3E	8	227	398	N/A	85	0	0	0	N/A
89072618	19	28.4N	135.2E	6	195	328	N/A	85	0	-5	10	N/A
89072700	20	29.2N	134.1E	5	27	30	N/A	85	0	0	5	N/A
89072706	21	30.1N	132.8E	0	74	N/A	N/A	90	-5	0	N/A	N/A
89072712	22	30.8N	131.2E	7	81	N/A	N/A	90	0	5	N/A	N/A
89072718	23	31.8N	130.0E	20	43	N/A	N/A	90	-15	10	N/A	N/A
89072800	24	32.7N	129.2E	7	52	N/A	N/A	65	0	5	N/A	N/A
89072806	25	33.5N	128.4E	15	N/A	N/A	N/A	60	5	N/A	N/A	N/A
89072812	26	34.6N	127.6E	20	N/A	N/A	N/A	50	5	N/A	N/A	N/A
89072818	27	36.4N	127.3E	30	N/A	N/A	N/A	40	10	N/A	N/A	N/A
89072900	28	38.0N	128.0E	7	N/A	N/A	N/A	30	0	N/A	N/A	N/A

Tropical Depression 12W

	00h	24h	48h	72h
Average	14	61	N/A	N/A
# Cases	3	2	0	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89072912	1	24.8N	124.0E	0	12	N/A	N/A	30	0	10	N/A	N/A
89072918	2	25.0N	122.8E	0	110	N/A	N/A	30	0	10	N/A	N/A
89073000	3	25.2N	122.0E	43	N/A	N/A	N/A	30	-5	N/A	N/A	N/A

Tropical Storm Ken-Lola (13W-14W)

	00h	24h	48h	72h
Average	38	193	313	382
# Cases	23	18	14	10

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89073000	1	24.3N	136.0E	20	221	509	519	30	0	-5	5	10
89073006	2	25.1N	137.3E	43	199	450	546	45	0	5	0	-10
89073012	3	26.5N	138.5E	31	397	449	306	45	0	5	5	-10
89073018	4	27.7N	136.7E	141	409	414	241	45	0	5	10	-10
89073100	5	28.5N	135.0E	246	N/A	N/A	N/A	45	0	N/A	N/A	N/A
89073112*	6	29.1N	130.9E	59	425	N/A	N/A	50	0	10	N/A	N/A
89073118	7	28.2N	129.9E	16	187	363	N/A	50	0	15	5	N/A
89080100	8	27.5N	129.5E	10	173	290	335	50	0	15	5	-10
89080106	9	27.0N	129.3E	26	151	285	378	50	0	10	10	5
89080112	10	26.8N	129.2E	43	221	362	386	45	0	10	-5	0
89080118	11	26.8N	129.0E	32	242	346	345	40	0	10	5	5
89080200	12	27.0N	128.9E	0	259	403	438	40	0	-5	10	15
89080206	13	27.7N	128.4E	18	171	311	324	45	0	10	40	30
89080212	14	28.5N	127.7E	7	30	39	N/A	45	0	15	5	N/A
89080218	15	29.5N	126.9E	37	92	76	N/A	45	-5	15	10	N/A
89080300	16	30.0N	126.0E	12	51	83	N/A	50	-10	0	5	N/A
89080306	17	30.4N	125.0E	18	106	N/A	N/A	50	-10	5	N/A	N/A
89080312	18	30.7N	123.8E	36	85	N/A	N/A	50	-10	0	N/A	N/A
89080318	19	31.1N	122.6E	11	51	N/A	N/A	45	-5	0	N/A	N/A
89080400	20	31.3N	121.3E	21	N/A	N/A	N/A	40	-5	N/A	N/A	N/A
89080406	21	31.8N	120.0E	43	N/A	N/A	N/A	30	0	N/A	N/A	N/A
89080412	22	32.0N	119.0E	5	N/A	N/A	N/A	30	0	N/A	N/A	N/A
89080418	23	32.1N	118.0E	11	N/A	N/A	N/A	25	0	N/A	N/A	N/A

* Post analysis indicates 13W and 14W were the same storm.

Typhoon Mac (15W)

	00h	24h	48h	72h
Average	17	167	335	520
# Cases	28	26	23	19

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89080100	1	21.2N	151.0E	36	120	230	279	30	5	15	15	10
89080106	2	21.8N	151.0E	21	73	221	299	30	10	15	5	10
89080112	3	22.5N	150.9E	12	141	244	426	35	5	15	0	10
89080118	4	23.2N	150.7E	12	137	352	551	40	5	15	-5	10
89080200	5	24.0N	150.2E	13	112	320	447	45	0	5	0	10
89080206	6	25.0N	149.8E	0	153	274	150	45	0	-5	0	10
89080212	7	26.1N	149.2E	16	227	325	283	45	5	-10	0	10
89080218	8	26.8N	148.2E	26	235	411	555	50	-5	-15	0	15
89080300	9	27.0N	147.1E	12	142	276	438	60	-5	0	10	25
89080306	10	26.9N	146.1E	6	119	264	465	70	5	20	15	30
89080312	11	26.7N	145.4E	0	110	347	622	75	0	10	15	50
89080318	12	26.5N	145.0E	10	139	435	725	80	-5	5	15	60
89080400	13	26.3N	144.6E	24	167	520	792	75	0	5	25	60
89080406	14	26.3N	144.3E	16	232	560	803	75	0	0	30	50
89080412	15	26.6N	144.1E	24	292	622	839	75	0	0	40	50
89080418	16	27.1N	144.0E	13	229	490	624	75	0	5	45	50
89080500	17	27.9N	143.9E	28	290	544	686	75	0	10	40	45
89080506	18	29.2N	143.7E	15	272	475	660	75	0	20	40	20
89080512	19	30.8N	143.2E	16	122	251	226	75	-5	20	20	15
89080518	20	32.6N	142.6E	19	46	212	N/A	70	5	30	5	N/A
89080600	21	34.2N	141.8E	19	34	169	N/A	65	5	10	10	N/A
89080606	22	35.8N	140.9E	12	98	35	N/A	50	15	5	5	N/A
89080612	23	37.4N	140.0E	11	136	125	N/A	40	5	5	5	N/A
89080618	24	39.1N	139.3E	24	274	N/A	N/A	30	5	5	N/A	N/A
89080700	25	40.4N	138.6E	36	230	N/A	N/A	30	10	5	N/A	N/A
89080706	26	41.2N	137.7E	21	224	N/A	N/A	30	5	-5	N/A	N/A
89080712	27	42.7N	136.6E	27	N/A	N/A	N/A	30	0	N/A	N/A	N/A
89080718	28	43.6N	137.0E	11	N/A	N/A	N/A	25	0	N/A	N/A	N/A

Typhoon Owen (16W)

	00h	24h	48h	72h
Average	21	115	239	380
# Cases	28	27	23	19

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89081100†	1	17.8N	143.4E	119	317	N/A	N/A	30	-5	0	N/A	N/A
89081106†	2	18.6N	144.1E	39	48	N/A	N/A	30	0	-5	N/A	N/A
89081112†	3	19.2N	144.8E	42	53	N/A	N/A	30	0	5	N/A	N/A
89081200	4	19.4N	147.1E	24	38	96	446	30	-5	-15	-30	-30
89081206	5	19.3N	147.6E	5	82	141	402	30	0	-5	-25	-30
89081212	6	19.2N	148.1E	18	74	163	463	35	-5	-15	-30	-30
89081218	7	18.8N	148.5E	30	155	318	548	35	0	-20	-30	-25
89081300	8	18.6N	149.2E	24	156	381	554	45	0	-5	-5	5
89081306	9	18.3N	150.1E	13	210	418	592	45	0	-5	-5	5
89081312	10	18.9N	151.1E	37	253	432	553	55	0	0	5	20
89081318	11	19.7N	151.7E	8	161	279	390	60	0	-5	5	30
89081400	12	20.8N	152.3E	12	76	165	368	65	0	0	15	20
89081406	13	22.2N	152.2E	8	95	216	437	70	0	10	10	10
89081412	14	23.7N	151.8E	13	95	230	292	75	0	10	10	5
89081418	15	25.2N	151.2E	12	140	236	220	75	5	15	20	15
89081500	16	26.2N	150.6E	8	87	177	96	75	0	5	15	15
89081506	17	27.2N	150.1E	12	102	162	93	75	0	0	5	15
89081512	18	28.4N	149.5E	7	138	168	145	75	0	-10	-10	-5
89081518	19	29.3N	148.7E	7	46	48	172	70	0	-5	-5	-5
89081600	20	30.4N	148.0E	24	78	301	542	70	-5	0	5	0
89081606	21	31.5N	147.4E	28	31	259	501	65	0	-5	0	0
89081612	22	32.4N	146.8E	13	53	233	412	65	0	-10	-5	5

† Tropical Depression Warning

Typhoon Owen (16W) (continued)

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89081618	23	33.3N	146.4E	7	103	311	N/A	55	0	-5	-5	N/A
89081700	24	34.7N	145.7E	24	198	367	N/A	55	-5	0	0	N/A
89081706	25	35.9N	145.8E	15	124	155	N/A	55	0	5	5	N/A
89081712	26	37.0N	146.3E	9	69	235	N/A	55	0	0	5	N/A
89081718	27	38.7N	147.1E	11	111	N/A	N/A	45	0	0	N/A	N/A
89081800	28	40.2N	147.9E	10	N/A	N/A	N/A	40	0	N/A	N/A	N/A

Typhoon Nancy (17W)

	00h	24h	48h	72h
Average	19	146	348	510
# Cases	22	20	19	16

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89081106	1	20.9N	155.1E	50	139	163	414	25	0	0	-20	-15
89081112	2	20.6N	156.0E	36	108	189	503	25	0	-10	-30	-25
89081118	3	20.3N	156.8E	16	104	354	672	30	0	-15	-35	-25
89081200	4	20.5N	157.6E	12	69	285	572	30	0	-20	-35	-20
89081206	5	21.1N	157.9E	23	42	342	624	35	-5	-25	-25	-15
89081212	6	21.7N	157.9E	8	155	477	708	45	-5	-20	-15	5
89081218	7	22.5N	157.8E	36	260	559	771	50	-5	-20	-10	5
89081300	8	23.4N	157.5E	20	240	515	713	55	0	-10	0	25
89081306	9	24.6N	157.0E	12	148	299	520	65	0	0	15	40
89081312	10	26.1N	156.4E	18	164	307	504	70	0	5	20	50
89081318	11	27.6N	155.2E	20	122	360	553	75	0	10	25	55
89081400	12	29.2N	154.0E	10	85	318	453	75	0	5	10	20
89081406	13	30.5N	151.7E	10	153	400	350	75	0	0	10	20
89081412	14	31.7N	149.9E	7	187	326	354	75	-5	-15	5	5
89081418	15	32.9N	148.4E	19	125	167	195	75	-10	-15	5	5
89081500	16	34.2N	147.0E	19	172	239	259	70	0	-5	10	10
89081506	17	35.7N	146.2E	6	128	174	N/A	65	0	5	15	N/A
89081512	18	37.3N	145.7E	7	148	515	N/A	65	0	15	20	N/A
89081518	19	38.9N	145.2E	9	142	628	N/A	65	-5	10	10	N/A
89081600	20	40.3N	145.2E	21	232	N/A	N/A	55	0	5	N/A	N/A
89081606	21	41.5N	145.4E	52	N/A	N/A	N/A	45	5	N/A	N/A	N/A
89081612	22	42.5N	145.6E	0	N/A	N/A	N/A	35	0	N/A	N/A	N/A

Tropical Storm Peggy (18W)

	00h	24h	48h	72h
Average	24	143	335	506
# Cases	9	8	6	2

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89081600	1	19.3N	148.8E	12	132	353	583	25	0	0	10	40
89081606	2	20.4N	148.8E	6	44	244	428	30	0	5	20	50
89081612	3	21.5N	148.7E	12	92	287	N/A	35	0	10	30	N/A
89081618	4	22.4N	148.4E	17	150	361	N/A	35	0	10	35	N/A
89081700	5	23.0N	148.1E	11	226	400	N/A	35	0	5	30	N/A
89081706	6	23.3N	147.6E	16	161	364	N/A	35	0	5	30	N/A
89081712	7	23.6N	147.1E	42	174	N/A	N/A	35	0	10	N/A	N/A
89081718	8	23.7N	146.2E	56	162	N/A	N/A	35	0	15	N/A	N/A
89081800	9	23.7N	145.3E	44	N/A	N/A	N/A	35	0	N/A	N/A	N/A

Tropical Depression 19W

	00h	24h	48h	72h
Average	19	95	N/A	N/A
# Cases	6	4	0	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89081700†	1	29.3N	124.2E	27	105	N/A	N/A	25	0	0	N/A	N/A
89081712†	2	28.1N	123.7E	40	160	N/A	N/A	25	5	0	N/A	N/A
89081800†	3	27.3N	123.2E	17	68	N/A	N/A	30	0	0	N/A	N/A
89081812†	4	27.2N	122.5E	12	47	N/A	N/A	30	0	5	N/A	N/A
89081900†	5	27.0N	121.8E	12	N/A	N/A	N/A	30	0	N/A	N/A	N/A
89081912†	6	26.8N	120.4E	5	N/A	N/A	N/A	25	0	N/A	N/A	N/A

† Tropical Depresion Warning

Tropical Storm Roger (20W)

	00h	24h	48h	72h
Average	32	223	473	949
# Cases	14	12	7	3

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89082412†	1	25.3N	124.0E	94	266	N/A	N/A	30	-5	-5	N/A	N/A
89082500	2	25.1N	124.7E	24	172	422	823	35	-5	0	-5	15
89082506	3	24.8N	125.6E	26	254	543	937	35	-5	0	5	15
89082512	4	24.5N	126.8E	28	345	708	1087	35	-5	0	5	15
89082518	5	24.4N	128.0E	33	412	816	N/A	35	-5	-15	0	N/A
89082600	6	26.1N	130.0E	17	165	406	N/A	40	-10	-20	-15	N/A
89082606	7	28.2N	131.2E	60	236	107	N/A	40	5	-10	-15	N/A
89082612	8	30.2N	131.9E	23	213	312	N/A	40	5	-10	-15	N/A
89082618	9	31.7N	133.0E	31	211	N/A	N/A	45	0	-10	N/A	N/A
89082700	10	33.3N	134.1E	12	208	N/A	N/A	50	0	0	N/A	N/A
89082706	11	35.2N	135.7E	18	105	N/A	N/A	40	5	0	N/A	N/A
89082712	12	37.0N	137.3E	33	92	N/A	N/A	40	5	-5	N/A	N/A
89082718	13	39.2N	139.3E	54	N/A	N/A	N/A	40	0	N/A	N/A	N/A
89082800	14	41.6N	140.9E	0	N/A	N/A	N/A	40	0	N/A	N/A	N/A

† Tropical Depression Warning

Tropical Depression 21W

	00h	24h	48h	72h
Average	23	135	N/A	N/A
# Cases	7	6	0	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89082506†	1	28.5N	151.6E	47	109	N/A	N/A	25	5	0	N/A	N/A
89082518†	2	30.1N	153.9E	13	143	N/A	N/A	30	0	5	N/A	N/A
89082606†	3	31.4N	155.7E	15	62	N/A	N/A	30	0	0	N/A	N/A
89082618†	4	31.4N	158.8E	33	81	N/A	N/A	30	0	0	N/A	N/A
89082706†	5	32.0N	161.0E	28	111	N/A	N/A	30	0	5	N/A	N/A
89082718†	6	32.2N	161.7E	11	303	N/A	N/A	30	0	-5	N/A	N/A
89082806†	7	32.7N	161.0E	16	N/A	N/A	N/A	25	0	N/A	N/A	N/A

† Tropical Depression Warning

Typhoon Sarah (22W)

	00h	24h	48h	72h
Average	28	165	302	450
# Cases	33	29	25	21

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89090600	1	20.9N	140.8E	16	180	313	790	30	-5	-5	-10	-5
89090606	2	20.6N	139.2E	11	108	164	355	30	0	-10	-10	-10
89090612	3	20.2N	137.8E	16	24	217	284	30	0	-15	-15	-5
89090618	4	20.0N	136.6E	13	76	145	24	35	0	-10	-10	5
89090700	5	20.0N	135.6E	6	172	186	12	40	-5	-5	-5	10

Typhoon Sarah (22W) (continued)

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89090706	6	20.1N	134.6E	24	220	136	145	45	0	5	10	30
89090712	7	20.5N	133.2E	16	231	220	124	50	-5	5	15	20
89090718	8	21.1N	131.4E	47	234	303	484	55	0	10	-5	-40
89090800	9	21.4N	129.1E	44	265	310	474	55	0	10	-5	-55
89090806	10	20.8N	126.9E	42	301	497	688	55	0	5	25	-35
89090812	11	19.7N	125.3E	34	321	586	726	60	-5	10	15	-75
89090818	12	18.5N	124.6E	61	90	354	507	65	0	20	5	-10
89090900	13	17.9N	124.3E	6	162	387	511	65	0	5	-55	-10
89090906	14	17.7N	123.9E	36	238	430	574	65	0	0	-60	5
89090912	15	17.9N	123.6E	39	253	419	517	60	5	-20	-65	10
89090918	16	18.4N	123.6E	78	281	386	542	55	10	-30	-30	25
89091000	17	19.1N	123.8E	17	91	83	360	55	10	-45	-5	40
89091006	18	19.9N	123.8E	18	68	148	406	55	10	-45	15	45
89091012	19	20.6N	123.6E	13	97	240	467	65	0	-40	30	60
89091018	20	21.1N	123.2E	6	78	224	483	75	0	-5	45	65
89091100	21	21.8N	123.1E	0	191	422	640	115	0	50	85	95
89091106	22	22.8N	122.7E	12	167	384	N/A	120	0	55	70	N/A
89091112	23	23.3N	122.0E	12	225	443	N/A	125	0	60	75	N/A
89091118	24	23.0N	121.2E	45	71	292	N/A	90	0	45	50	N/A
89091200	25	23.0N	121.6E	13	146	269	N/A	80	0	40	55	N/A
89091206	26	24.1N	122.0E	18	190	N/A	N/A	65	0	25	N/A	N/A
89091212	27	24.5N	121.3E	20	154	N/A	N/A	60	0	25	N/A	N/A
89091218	28	25.1N	120.9E	39	137	N/A	N/A	45	10	30	N/A	N/A
89091300	29	25.7N	120.3E	32	27	N/A	N/A	40	5	10	N/A	N/A
89091306	30	26.3N	119.8E	56	N/A	N/A	N/A	35	10	N/A	N/A	N/A
89091312	31	27.1N	119.6E	41	N/A	N/A	N/A	30	0	N/A	N/A	N/A
89091318	32	27.9N	119.8E	48	N/A	N/A	N/A	25	5	N/A	N/A	N/A
89091400	33	28.7N	120.0E	50	N/A	N/A	N/A	20	0	N/A	N/A	N/A

Tropical Storm Tip (23W)

	00h	24h	48h	72h
Average	23	204	374	502
# Cases	20	18	11	8

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89090900	1	20.3N	153.9E	71	369	318	385	25	0	10	20	30
89090906	2	22.1N	154.9E	37	298	226	375	30	0	N/A	N/A	N/A
89090912	3	24.5N	155.0E	0	78	183	418	30	0	10	20	20
89090918	4	26.7N	154.0E	0	113	258	392	30	0	15	25	20
89091000	5	28.2N	152.3E	0	207	315	490	35	0	20	30	20
89091006	6	28.9N	151.0E	32	281	335	582	35	0	20	25	20
89091012	7	29.3N	150.2E	78	172	323	575	35	0	20	5	-10
89091018	8	29.8N	150.0E	20	213	477	800	35	0	5	0	10
89091100	9	30.4N	150.4E	6	24	N/A	N/A	35	0	-5	N/A	N/A
89091106	10	31.6N	151.0E	5	120	474	N/A	35	5	0	-10	N/A
89091112	11	33.0N	151.1E	7	268	648	N/A	35	5	-10	-20	N/A
89091118	12	34.0N	151.1E	11	256	565	N/A	35	0	-15	-15	N/A
89091200	13	35.0N	151.8E	7	327	N/A	N/A	35	5	-15	N/A	N/A
89091206	14	35.6N	152.7E	18	249	N/A	N/A	40	10	-15	N/A	N/A
89091212	15	36.0N	154.5E	4	174	N/A	N/A	45	0	-10	N/A	N/A
89091218	16	36.6N	156.6E	9	214	N/A	N/A	45	0	-10	N/A	N/A
89091300	17	36.6N	159.0E	15	143	N/A	N/A	50	0	0	N/A	N/A
89091306	18	36.5N	161.1E	20	163	N/A	N/A	50	0	0	N/A	N/A
89091312	19	36.6N	163.1E	15	N/A	N/A	N/A	45	0	N/A	N/A	N/A
89091318	20	36.6N	165.1E	108	N/A	N/A	N/A	45	5	N/A	N/A	N/A

Tropical Storm Vera (24W)

	00h	24h	48h	72h
Average	25	173	381	662
# Cases	16	13	10	7

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89091206	1	18.0N	144.2E	42	397	652	895	30	0	-10	10	35
89091212	2	18.7N	142.7E	12	181	355	653	35	0	-5	15	35
89091218	3	19.6N	140.9E	32	256	533	729	40	5	25	60	90
89091300	4	20.3N	139.2E	18	110	362	590	45	5	20	60	90
89091306	5	20.8N	137.5E	17	128	359	536	50	5	30	60	95
89091312	6	21.3N	135.7E	51	293	518	650	50	0	20	40	65
89091318	7	21.9N	133.9E	39	144	352	582	45	0	20	40	25
89091400	8	22.7N	131.9E	12	141	260	N/A	45	0	20	40	N/A
89091406	9	23.4N	129.9E	12	72	136	N/A	45	0	0	5	N/A
89091412	10	24.2N	128.0E	28	110	285	N/A	45	0	0	10	N/A
89091418	11	24.9N	126.2E	12	122	N/A	N/A	40	0	5	N/A	N/A
89091500	12	26.2N	124.5E	12	101	N/A	N/A	40	0	10	N/A	N/A
89091506	13	27.3N	122.9E	12	198	N/A	N/A	40	0	10	N/A	N/A
89091512	14	28.4N	121.6E	28	N/A	N/A	N/A	40	-5	N/A	N/A	N/A
89091518	15	29.3N	120.7E	33	N/A	N/A	N/A	30	0	N/A	N/A	N/A
89091600	16	30.2N	119.9E	35	N/A	N/A	N/A	30	0	N/A	N/A	N/A

Typhoon Wayne (25W)

	00h	24h	48h	72h
Average	19	231	623	N/A
# Cases	12	10	4	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89091706†	1	23.7N	124.9E	5	115	N/A	N/A	25	0	-10	N/A	N/A
89091718	2	24.1N	125.1E	87	348	N/A	N/A	30	-5	-25	N/A	N/A
89091800	3	25.3N	125.2E	5	424	N/A	N/A	35	0	-20	-20	N/A
89091806	4	26.6N	125.3E	16	144	593	N/A	40	-5	-20	-20	N/A
89091812	5	27.7N	125.8E	12	292	753	N/A	45	0	-15	-20	N/A
89091818	6	29.0N	127.1E	16	344	720	N/A	55	0	-10	-5	N/A
89091900	7	30.3N	128.6E	15	309	N/A	N/A	65	0	-15	N/A	N/A
89091906	8	31.5N	131.4E	6	157	N/A	N/A	65	0	5	N/A	N/A
89091912	9	32.9N	134.6E	0	290	N/A	N/A	65	0	10	N/A	N/A
89091918	10	34.4N	138.6E	23	284	N/A	N/A	60	-5	5	N/A	N/A
89092000	11	36.3N	143.0E	20	N/A	N/A	N/A	55	0	N/A	N/A	N/A
89092006	12	38.4N	147.8E	26	N/A	N/A	N/A	50	0	N/A	N/A	N/A

† Tropical Depression Warning

Super Typhoon Angela (26W)

	00h	24h	48h	72h
Average	8	68	165	293
# Cases	46	43	39	35

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89092906	1	13.5N	139.7E	8	104	276	293	30	0	5	-25	-25
89092912	2	14.3N	139.3E	13	98	207	348	30	0	0	-35	-45
89092918	3	15.1N	139.0E	11	116	233	395	35	0	-10	-35	-45
89093000	4	15.5N	138.6E	5	30	165	421	40	0	-35	-45	-45
89093006	5	15.8N	138.4E	5	61	226	477	40	0	-30	-45	-45
89093012	6	16.0N	138.3E	8	103	321	653	45	0	-35	-45	-35
89093018	7	16.4N	138.1E	6	117	355	666	65	0	-5	-5	5
89100100	8	16.5N	137.7E	5	157	393	686	90	0	0	-5	-20
89100106	9	16.7N	137.3E	8	109	154	300	90	0	0	-15	-25
89100112	10	16.8N	136.7E	5	123	255	529	100	0	-5	-15	-20
89100118	11	17.1N	136.1E	8	203	392	812	105	0	-5	-10	-30
89100200	12	17.3N	135.2E	5	37	70	267	115	0	-15	-20	-40
89100206	13	17.5N	134.2E	23	45	66	242	115	0	0	-10	-35
89100212	14	17.8N	133.4E	12	66	191	412	120	0	10	-5	-35

Super Typhoon Angela (26W) (continued)

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89100218	15	18.0N	132.7E	0	81	218	436	120	0	15	-15	-35
89100300	16	18.1N	131.9E	5	85	115	92	120	0	0	-20	-35
89100306	17	18.2N	131.2E	6	32	126	216	120	-5	0	-25	-25
89100312	18	18.2N	130.7E	8	63	156	204	120	-5	0	-25	20
89100318	19	18.2N	130.1E	8	97	188	227	115	0	-15	-30	15
89100400	20	18.2N	129.4E	5	125	263	388	115	-5	-30	-45	5
89100406	21	18.2N	128.5E	0	39	72	54	115	0	-15	-50	5
89100412	22	18.2N	127.3E	17	41	68	87	115	0	-20	-10	10
89100418	23	18.2N	126.0E	0	53	87	132	125	0	-35	-5	15
89100500	24	18.1N	125.0E	6	74	118	193	125	0	-60	-20	-25
89100506	25	18.1N	123.9E	8	75	121	180	130	0	-40	-5	-40
89100512	26	18.2N	122.9E	20	71	114	173	130	0	0	0	-45
89100518	27	18.4N	122.0E	0	47	188	298	130	0	0	0	-45
89100600	28	18.6N	121.1E	13	49	108	125	125	0	35	15	-30
89100606	29	18.7N	120.1E	12	75	141	126	115	0	20	-20	-50
89100612	30	18.7N	119.3E	5	75	128	101	75	-10	-10	-45	-60
89100618	31	18.6N	118.6E	13	30	47	33	75	0	-10	-45	-55
89100700	32	18.5N	117.9E	8	16	68	146	75	0	-15	-50	-60
89100706	33	18.3N	117.2E	12	25	94	177	70	0	-35	-60	-60
89100712	34	18.2N	116.5E	8	13	86	144	65	0	-45	-55	-35
89100718	35	18.2N	115.8E	12	78	149	213	65	0	-45	-50	-5
89100800	36	18.2N	115.1E	8	51	114	N/A	70	0	-10	-10	N/A
89100806	37	18.1N	114.4E	12	80	160	N/A	85	0	-5	0	N/A
89100812	38	17.9N	113.5E	12	86	154	N/A	90	0	-5	15	N/A
89100818	39	17.7N	112.5E	5	12	58	N/A	90	0	-10	0	N/A
89100900	40	17.6N	111.6E	6	17	N/A	N/A	90	0	-15	N/A	N/A
89100906	41	17.5N	110.7E	8	38	N/A	N/A	95	0	-5	N/A	N/A
89100912	42	17.5N	109.6E	8	29	N/A	N/A	90	0	-15	N/A	N/A
89100918	43	17.4N	108.6E	6	12	N/A	N/A	85	0	20	N/A	N/A
89101000	44	17.4N	107.8E	11	N/A	N/A	N/A	85	-10	N/A	N/A	N/A
89101006	45	17.4N	106.9E	20	N/A	N/A	N/A	80	-5	N/A	N/A	N/A
89101012	46	17.4N	106.0E	8	N/A	N/A	N/A	60	0	N/A	N/A	N/A

Typhoon Brian (27W)

	00h	24h	48h	72h
Average	16	104	135	N/A
# Cases	13	10	5	N/A

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89093006†	1	20.0N	115.5E	45	197	N/A	N/A	25	0	-25	N/A	N/A
89093018	2	19.9N	115.2E	16	142	190	N/A	35	0	-10	-40	N/A
89100100	3	19.5N	114.8E	5	130	123	N/A	45	0	0	-45	N/A
89100106	4	19.2N	114.3E	12	29	142	N/A	55	0	-5	-45	N/A
89100112	5	18.9N	113.7E	12	20	95	N/A	55	0	-15	-5	N/A
89100118	6	18.6N	113.1E	0	41	124	N/A	65	0	-20	10	N/A
89100200	7	18.4N	112.4E	5	108	N/A	N/A	65	0	-20	N/A	N/A
89100206	8	18.4N	111.5E	23	165	N/A	N/A	70	-5	-20	N/A	N/A
89100212	9	18.4N	110.5E	34	184	N/A	N/A	80	-5	15	N/A	N/A
89100218	10	18.4N	109.3E	11	20	N/A	N/A	75	0	0	N/A	N/A
89100300	11	18.5N	107.8E	18	N/A	N/A	N/A	75	0	N/A	N/A	N/A
89100306	12	18.7N	106.4E	8	N/A	N/A	N/A	75	0	N/A	N/A	N/A
89100312	13	19.1N	105.1E	16	N/A	N/A	N/A	45	0	N/A	N/A	N/A

† Tropical Depression Warning

Typhoon Colleen (28W)

	00h	24h	48h	72h
Average	18	153	207	303
# Cases	27	24	20	16

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89100118	1	11.6N	150.3E	16	85	286	447	30	0	10	15	15
89100200	2	11.7N	149.3E	13	179	365	511	35	0	15	15	20
89100206	3	12.0N	148.4E	41	239	402	549	35	5	15	10	20
89100212	4	12.5N	147.9E	29	217	387	519	35	5	15	10	15
89100218	5	13.1N	147.5E	18	217	270	322	40	0	5	5	20
89100300	6	14.0N	147.3E	18	123	127	147	45	0	5	10	20
89100306	7	15.1N	147.1E	34	79	236	312	45	0	-10	-10	-25
89100312	8	16.1N	146.5E	39	191	228	134	50	0	-5	-5	0
89100318	9	17.2N	145.9E	32	80	142	147	55	0	-5	0	0
89100400	10	18.1N	145.5E	12	91	117	142	60	0	10	15	20
89100406	11	18.9N	145.1E	5	119	150	184	65	0	10	15	20
89100412	12	19.6N	144.8E	8	94	141	91	70	-5	5	15	20
89100418	13	20.2N	144.6E	29	155	251	135	75	0	15	25	20
89100500	14	20.7N	144.5E	13	38	143	182	75	5	25	30	20
89100506	15	21.2N	144.2E	8	82	115	410	75	0	25	30	20
89100512	16	21.9N	143.8E	17	133	70	616	80	-5	25	15	-5
89100518	17	22.7N	143.2E	27	174	37	N/A	75	0	25	15	N/A
89100600	18	23.6N	142.6E	0	97	81	N/A	75	0	0	-10	N/A
89100606	19	24.6N	141.8E	16	102	111	N/A	75	0	-5	-15	N/A
89100612	20	25.4N	141.1E	10	80	479	N/A	75	0	-5	-10	N/A
89100618	21	26.4N	140.5E	6	163	N/A	N/A	75	0	-5	N/A	N/A
89100700	22	27.7N	140.7E	28	337	N/A	N/A	70	5	-5	N/A	N/A
89100706	23	29.3N	141.5E	5	183	N/A	N/A	70	0	-10	N/A	N/A
89100712	24	31.0N	143.0E	13	419	N/A	N/A	70	0	-5	N/A	N/A
89100718	25	33.4N	145.4E	13	N/A	N/A	N/A	70	0	N/A	N/A	N/A
89100800	26	36.5N	148.5E	4	N/A	N/A	N/A	70	0	N/A	N/A	N/A
89100806	27	40.4N	153.3E	37	N/A	N/A	N/A	70	0	N/A	N/A	N/A

Typhoon Dan (29W)

	00h	24h	48h	72h
Average	16	105	222	375
# Cases	21	18	13	10

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89100812	1	10.3N	138.4E	58	260	459	663	25	0	-20	-10	15
89100818	2	10.5N	136.9E	24	136	345	576	30	0	-10	-10	15
89100900	3	10.7N	135.4E	8	113	277	438	40	-10	-15	-10	10
89100906	4	10.9N	133.7E	13	126	311	438	50	-15	-10	10	0
89100912	5	11.1N	131.9E	12	59	260	357	55	-10	5	0	0
89100918	6	11.4N	130.0E	24	8	152	216	55	0	-5	15	35
89101000	7	11.8N	128.1E	16	133	270	331	55	-5	5	10	25
89101006	8	12.4N	126.2E	18	134	235	308	65	0	15	10	25
89101012	9	12.9N	124.3E	5	100	145	258	65	5	20	15	35
89101018	10	13.5N	122.6E	31	94	101	170	65	5	25	25	15
89101100	11	14.2N	120.7E	18	70	120	N/A	65	0	15	20	N/A
89101106	12	15.2N	118.8E	0	68	114	N/A	60	5	10	20	N/A
89101112	13	16.0N	116.8E	24	114	91	N/A	60	5	15	-5	N/A
89101118	14	16.4N	115.1E	37	223	N/A	N/A	60	5	-15	N/A	N/A
89101200	15	16.5N	113.5E	13	47	N/A	N/A	65	0	10	N/A	N/A
89101206	16	16.7N	112.3E	5	93	N/A	N/A	70	0	10	N/A	N/A
89101212	17	17.0N	111.1E	13	74	N/A	N/A	70	0	20	N/A	N/A
89101218	18	17.4N	109.8E	8	45	N/A	N/A	65	5	20	N/A	N/A
89101300	19	17.8N	108.6E	5	N/A	N/A	N/A	65	0	N/A	N/A	N/A
89101306	20	18.1N	107.3E	5	N/A	N/A	N/A	65	0	N/A	N/A	N/A
89101312	21	18.3N	106.0E	0	N/A	N/A	N/A	55	0	N/A	N/A	N/A

Super Typhoon Elsie (30W)

	00h	24h	48h	72h
Average	12	75	145	231
# Cases	34	31	27	23

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89101400	1	16.4N	132.2E	0	138	288	392	30	0	0	-15	-55
89101406	2	16.3N	131.8E	8	121	272	353	30	5	0	-15	-50
89101412	3	16.2N	131.6E	13	24	54	44	35	0	-10	-40	-65
89101418	4	16.2N	131.4E	11	29	75	46	35	0	-10	-45	-60
89101500	5	16.1N	131.2E	17	46	62	40	40	-5	-10	-50	-55
89101506	6	16.1N	130.9E	12	54	56	12	45	-5	-20	-55	-60
89101512	7	16.1N	130.8E	21	67	54	42	50	-5	-35	-60	-55
89101518	8	16.1N	130.7E	11	48	29	71	55	0	-30	-35	-40
89101600	9	16.2N	130.6E	8	66	63	135	60	-5	-35	-35	-40
89101606	10	16.5N	130.3E	12	65	98	201	70	-5	-35	-40	20
89101612	11	16.7N	130.0E	5	69	109	226	90	0	-10	-10	60
89101618	12	16.9N	129.4E	5	66	77	242	100	0	0	-10	75
89101700	13	16.9N	128.8E	12	74	114	311	110	0	-40	-65	25
89101706	14	16.9N	128.1E	13	74	71	261	115	-5	-30	-5	20
89101712	15	16.7N	127.5E	26	79	119	243	125	-15	-30	15	35
89101718	16	16.4N	126.9E	26	52	93	175	125	-5	-30	25	45
89101800	17	16.1N	126.4E	8	42	173	252	125	-5	-40	25	45
89101806	18	16.1N	125.7E	13	137	260	348	130	0	40	15	50
89101812	19	16.2N	124.9E	21	176	289	395	130	0	60	20	55
89101818	20	16.4N	124.1E	5	142	254	374	140	-5	20	30	65
89101900	21	16.6N	122.9E	8	111	220	387	140	-5	30	40	65
89101906	22	16.7N	121.5E	23	123	236	398	80	40	35	45	65
89101912	23	16.8N	119.9E	13	62	217	374	60	20	40	55	80
89101918	24	16.8N	118.4E	11	65	222	N/A	55	30	40	65	N/A
89102000	25	16.9N	117.1E	6	36	156	N/A	55	35	45	70	N/A
89102006	26	16.9N	116.0E	8	42	152	N/A	55	15	10	15	N/A
89102012	27	17.0N	114.8E	11	60	104	N/A	55	5	10	5	N/A
89102018	28	17.2N	113.7E	13	87	N/A	N/A	55	0	15	N/A	N/A
89102100	29	17.5N	112.5E	8	45	N/A	N/A	55	0	5	N/A	N/A
89102106	30	17.8N	111.4E	6	70	N/A	N/A	50	0	5	N/A	N/A
89102112	31	18.2N	109.9E	11	54	N/A	N/A	40	0	10	N/A	N/A
89102118	32	18.3N	108.5E	13	N/A	N/A	N/A	35	5	N/A	N/A	N/A
89102200	33	18.3N	107.2E	12	N/A	N/A	N/A	35	0	N/A	N/A	N/A
89102206	34	18.3N	105.9E	29	N/A	N/A	N/A	35	-5	N/A	N/A	N/A

Typhoon Forrest (31W)

	00h	24h	48h	72h
Average	22	93	169	318
# Cases	30	27	23	18

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89102200	1	8.9N	150.2E	34	124	248	359	30	0	0	0	15
89102206	2	9.8N	149.5E	5	109	213	304	30	0	-5	5	20
89102212	3	10.7N	149.0E	13	122	223	303	35	0	-5	5	30
89102218	4	11.5N	148.5E	34	104	180	248	40	0	0	10	30
89102300	5	12.2N	148.1E	8	55	100	165	45	0	5	15	20
89102306	6	12.9N	147.6E	12	72	105	212	50	0	10	20	45
89102312	7	13.4N	147.0E	13	64	133	240	55	0	10	15	45
89102318	8	13.8N	146.4E	8	64	122	253	60	0	10	10	40
89102400	9	14.3N	145.8E	13	72	168	313	60	0	-5	0	5
89102406	10	15.0N	145.1E	16	36	86	216	60	0	-5	5	5
89102412	11	15.6N	144.4E	49	66	42	198	65	0	-5	5	5
89102418	12	16.1N	143.7E	24	164	282	361	70	0	0	20	30
89102500	13	16.6N	142.8E	6	96	210	358	75	-5	0	15	20
89102506	14	17.2N	141.9E	5	49	98	283	80	-5	5	15	20
89102512	15	17.9N	141.0E	8	53	124	386	85	0	20	20	25
89102518	16	18.6N	140.3E	26	109	186	513	90	0	20	25	30
89102600	17	19.4N	139.6E	0	16	132	457	90	0	5	10	20

Typhoon Forrest (31W) (continued)

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WN ER	24 ER	48 ER	72 ER
89102606	18	20.4N	139.1E	12	34	31	558	90	0	5	20	20
89102612	19	21.1N	138.5E	24	247	679	N/A	90	-5	-30	-30	N/A
89102618	20	21.9N	138.1E	20	116	261	N/A	90	-5	-15	-20	N/A
89102700	21	22.7N	137.7E	0	70	139	N/A	95	0	-5	0	N/A
89102706	22	23.6N	137.5E	18	33	96	N/A	95	0	0	0	N/A
89102712	23	24.6N	137.4E	12	99	33	N/A	95	0	-10	-5	N/A
89102718	24	25.8N	137.5E	20	106	N/A	N/A	90	0	-5	N/A	N/A
89102800	25	27.1N	138.1E	41	94	N/A	N/A	90	0	5	N/A	N/A
89102806	26	28.4N	139.4E	33	155	N/A	N/A	80	0	0	N/A	N/A
89102812	27	29.9N	141.4E	43	180	N/A	N/A	75	0	-5	N/A	N/A
89102818	28	31.7N	144.3E	70	N/A	N/A	N/A	70	0	N/A	N/A	N/A
89102900	29	33.9N	148.3E	50	N/A	N/A	N/A	60	0	N/A	N/A	N/A
89102906	30	36.8N	153.0E	48	N/A	N/A	N/A	60	-10	N/A	N/A	N/A

Typhoon Gay (32W)

	00h	24h	48h	72h
Average	11	67	132	209
# Cases	34	30	25	20

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WN ER	24 ER	48 ER	72 ER
89110200	1	8.2N	102.2E	5	63	N/A	N/A	35	-10	-35	N/A	N/A
89110206	2	8.3N	102.0E	17	72	54	37	35	0	-25	-50	-25
89110212	3	8.7N	101.9E	13	46	43	111	35	0	-45	-20	-35
89110218	4	9.1N	101.8E	0	24	94	205	45	-10	-50	-25	-35
89110300	5	9.3N	101.5E	8	16	79	200	65	-20	-45	-35	-30
89110306	6	9.8N	101.2E	0	26	90	224	75	-20	-30	-25	-15
89110312	7	10.2N	100.8E	0	37	123	264	90	-30	-5	-20	-10
89110318	8	10.4N	100.3E	0	31	112	253	95	-30	-10	-15	-5
89110400	9	10.5N	99.9E	11	100	213	283	100	-30	5	5	10
89110406	10	10.7N	99.2E	17	102	206	288	100	-15	0	5	5
89110412	11	11.2N	98.3E	0	59	204	291	65	15	5	15	10
89110418	12	11.3N	97.5E	11	47	181	274	75	5	5	15	5
89110500	13	11.4N	96.8E	13	91	210	294	85	0	5	10	0
89110506	14	11.7N	95.9E	8	121	211	279	90	0	5	5	-10
89110512	15	12.0N	94.8E	8	113	169	196	95	-5	5	0	-15
89110518	16	12.2N	93.8E	18	100	149	168	95	-5	5	-5	-20
89110600	17	12.4N	92.6E	17	83	110	151	95	-5	-10	-35	-10
89110606	18	13.0N	91.4E	38	67	102	173	95	-5	-25	-55	25
89110612	19	13.4N	90.2E	0	24	51	158	95	-10	-35	-65	5
89110618	20	13.7N	89.1E	11	21	77	162	95	-5	-35	-75	0
89110700	21	13.9N	88.1E	0	25	105	159	100	0	-20	-5	10
89110706	22	14.2N	87.1E	0	56	137	N/A	105	-5	-30	25	N/A
89110712	23	14.5N	86.1E	0	77	141	N/A	110	-10	-35	15	N/A
89110718	24	14.6N	85.0E	8	79	128	N/A	115	-5	-55	20	N/A
89110800	25	14.6N	83.8E	13	77	121	N/A	120	-5	-20	10	N/A
89110806	26	14.6N	82.6E	5	30	180	N/A	130	10	35	25	N/A
89110812	27	14.7N	81.5E	18	75	N/A	N/A	135	10	35	N/A	N/A
89110818	28	14.8N	80.4E	6	102	N/A	N/A	140	0	20	N/A	N/A
89110900	29	15.1N	79.1E	13	130	N/A	N/A	90	15	30	N/A	N/A
89110906	30	15.4N	77.7E	18	109	N/A	N/A	45	45	20	N/A	N/A
89110912	31	15.8N	76.5E	16	N/A	N/A	N/A	35	35	N/A	N/A	N/A
89110918	32	16.6N	75.5E	43	N/A	N/A	N/A	25	25	N/A	N/A	N/A
89111000	33	17.6N	74.6E	49	N/A	N/A	N/A	20	15	N/A	N/A	N/A
89111006	34	18.1N	74.0E	0	N/A	N/A	N/A	15	15	N/A	N/A	N/A

Typhoon Hunt (33W)

	00h	24h	48h	72h
Average	14	98	173	207
# Cases	27	25	23	19

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89111612	1	12.0N	132.7E	18	92	250	434	25	0	5	-10	-40
89111618	2	12.0N	131.7E	18	165	309	486	25	0	0	-20	-40
89111700	3	11.9N	131.0E	31	128	242	402	25	0	-5	-30	-40
89111706	4	11.8N	130.6E	24	102	181	250	30	0	-15	-45	-40
89111712	5	11.8N	130.0E	13	105	222	290	30	0	-20	-40	-40
89111718	6	12.1N	129.4E	17	109	260	306	35	0	-15	-35	-35
89111800	7	12.5N	128.9E	18	109	217	278	40	0	-15	-25	-25
89111806	8	13.0N	128.4E	6	113	245	300	50	0	-20	-20	-10
89111812	9	13.5N	127.9E	13	119	285	278	60	0	-15	-30	-20
89111818	10	14.0N	127.5E	24	55	133	119	65	0	-15	-15	-30
89111900	11	14.3N	127.2E	8	107	146	157	75	0	0	0	-5
89111906	12	14.6N	127.0E	8	84	116	121	90	0	10	10	15
89111912	13	15.0N	127.0E	5	35	52	42	90	0	10	10	25
89111918	14	15.4N	126.9E	11	47	67	36	90	0	10	0	30
89112000	15	15.4N	126.5E	18	86	80	57	90	0	0	25	30
89112006	16	15.4N	126.1E	5	91	103	63	90	0	0	40	35
89112012	17	15.3N	125.7E	8	95	98	63	90	0	0	40	40
89112018	18	15.2N	125.1E	16	81	89	84	90	0	-5	35	35
89112100	19	15.0N	124.2E	5	106	179	174	90	0	-5	30	25
89112106	20	15.1N	123.3E	13	117	191	N/A	90	0	15	30	N/A
89112112	21	15.2N	122.5E	11	123	212	N/A	90	0	25	30	N/A
89112118	22	15.5N	121.7E	18	88	136	N/A	90	-5	25	25	N/A
89112200	23	15.9N	121.1E	8	69	171	N/A	75	0	20	30	N/A
89112206	24	16.1N	120.3E	35	140	N/A	N/A	55	0	15	N/A	N/A
89112212	25	16.3N	119.6E	11	75	N/A	N/A	40	0	0	N/A	N/A
89112218	26	16.4N	119.2E	12	N/A	N/A	N/A	35	0	N/A	N/A	N/A
89112300	27	16.5N	118.7E	5	N/A	N/A	N/A	30	0	N/A	N/A	N/A

Super Typhoon Irma (34W)

	00h	24h	48h	72h
Average	18	112	212	394
# Cases	39	37	27	23

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89112106†	1	17.7N	164.8E	11	181	N/A	N/A	25	-5	0	N/A	N/A
89112118†	2	19.2N	163.0E	30	120	N/A	N/A	25	0	0	N/A	N/A
89112206†	3	19.7N	162.3E	12	160	N/A	N/A	25	-5	-10	N/A	N/A
89112500*	4	13.7N	150.6E	26	55	N/A	N/A	30	-5	0	N/A	N/A
89112512†	5	12.8N	148.4E	26	205	N/A	N/A	30	0	-5	N/A	N/A
89112600†	6	11.7N	147.0E	17	110	N/A	N/A	30	0	-15	N/A	N/A
89112612	7	10.7N	145.9E	16	94	144	213	35	-5	-15	-25	-45
89112618	8	10.4N	145.2E	24	117	168	249	35	0	-10	-20	-60
89112700	9	10.1N	144.5E	8	32	125	163	45	0	5	-10	-25
89112706	10	10.0N	144.0E	0	64	172	186	45	0	0	-15	-25
89112712	11	10.0N	143.4E	41	143	236	251	50	0	0	-15	-30
89112718	12	10.1N	142.7E	18	74	152	174	55	0	0	-30	-25
89112800	13	10.2N	141.9E	8	130	181	186	60	0	-20	-40	-5
89112806	14	10.4N	141.0E	8	135	177	142	65	0	-20	-40	5
89112812	15	10.8N	140.0E	6	71	100	92	70	0	-15	-30	10
89112818	16	11.3N	138.9E	11	26	84	105	75	0	-35	-45	-15
89112900	17	11.8N	137.8E	0	32	34	107	100	0	-15	-5	-5
89112906	18	12.3N	136.7E	5	37	36	125	105	0	-15	-5	-5
89112912	19	12.6N	135.7E	13	48	115	256	105	0	-50	-40	-25
89112918	20	12.9N	135.0E	5	40	77	250	125	-20	-40	-30	-25
89113000	21	13.2N	134.2E	8	36	112	358	140	-20	-5	0	5
89113006	22	13.5N	133.4E	11	63	206	481	140	0	-5	0	5

† Tropical Depression Warning
* Regenerated

Super Typhoon Irma (34W) (continued)

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89113012	23	13.8N	132.5E	5	100	235	546	140	0	20	20	10
89113018	24	14.1N	132.0E	12	54	238	590	135	0	10	0	-10
89120100	25	14.3N	131.6E	8	105	343	782	120	5	0	-5	0
89120106	26	14.5N	131.2E	32	123	428	906	115	0	-5	0	10
89120112	27	14.7N	131.0E	5	132	481	933	110	0	-5	-5	15
89120118	28	14.9N	130.7E	11	135	498	946	105	0	-10	-5	25
89120200	29	15.2N	130.6E	11	195	614	1027	100	0	-10	0	30
89120206	30	15.6N	130.7E	23	196	516	N/A	95	-5	-15	0	N/A
89120212	31	16.1N	130.9E	8	13	31	N/A	90	0	5	15	N/A
89120218	32	16.7N	131.3E	21	43	117	N/A	90	0	0	25	N/A
89120300	33	17.2N	131.9E	16	78	108	N/A	85	0	5	35	N/A
89120306	34	18.1N	132.8E	11	30	N/A	N/A	80	0	10	N/A	N/A
89120312	35	19.1N	133.7E	8	94	N/A	N/A	75	0	15	N/A	N/A
89120318	36	20.1N	134.5E	21	189	N/A	N/A	75	0	15	N/A	N/A
89120400	37	21.0N	136.1E	21	694	N/A	N/A	65	0	20	N/A	N/A
89120406	38	21.7N	137.4E	43	N/A	N/A	N/A	55	5	N/A	N/A	N/A
89120412	39	22.5N	138.8E	131	N/A	N/A	N/A	45	0	N/A	N/A	N/A

Tropical Depression 35W

	00h	24h	48h	72h
Average	73	212	439	N/A
# Cases	9	5	1	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89120700	1	11.0N	139.1E	106	232	439	N/A	30	-5	5	25	N/A
89120706	2	10.9N	138.7E	40	46	N/A	N/A	30	0	10	N/A	N/A
89120712	3	10.9N	138.4E	79	129	N/A	N/A	30	0	10	N/A	N/A
89120718	4	11.0N	138.2E	97	272	N/A	N/A	30	0	10	N/A	N/A
89120800	5	11.1N	138.0E	144	381	N/A	N/A	30	0	15	N/A	N/A
89120806	6	11.5N	138.0E	64	N/A	N/A	N/A	30	0	N/A	N/A	N/A
89120812	7	12.2N	138.3E	61	N/A	N/A	N/A	30	0	N/A	N/A	N/A
89120818	8	12.8N	138.7E	5	N/A	N/A	N/A	30	0	N/A	N/A	N/A
89120900	9	13.5N	139.0E	61	N/A	N/A	N/A	25	0	N/A	N/A	N/A

Typhoon Jack (36W)

	00h	24h	48h	72h
Average	28	95	167	317
# Cases	21	20	18	14

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
89122300	1	10.2N	152.7E	6	98	N/A	N/A	30	-5	-35	N/A	N/A
89122306	2	10.9N	151.9E	0	108	191	338	35	0	-20	-50	-55
89122312	3	11.5N	151.2E	13	133	258	458	45	0	-25	-50	-60
89122318	4	11.9N	150.9E	47	6	58	215	55	0	-15	-40	-55
89122400	5	12.2N	150.5E	13	48	105	304	65	0	-15	-35	-25
89122406	6	12.5N	150.1E	8	26	138	336	70	-5	-25	-35	-10
89122412	7	12.7N	149.6E	18	37	168	355	80	-5	-20	-20	25
89122418	8	12.8N	149.2E	8	102	217	352	90	0	-25	-15	45
89122500	9	12.9N	148.8E	0	94	222	234	100	-5	-10	15	75
89122506	10	13.4N	148.5E	18	87	212	168	110	-5	-5	30	80
89122512	11	13.6N	148.3E	8	88	198	193	120	-10	-5	60	85
89122518	12	13.7N	148.2E	11	81	159	303	125	-5	5	75	80
89122600	13	13.8N	148.1E	8	75	56	303	125	0	20	85	75
89122606	14	13.8N	148.0E	5	56	36	371	125	-5	30	85	75
89122612	15	13.8N	148.0E	5	51	139	511	125	-5	50	85	80
89122618	16	13.7N	147.9E	13	44	200	N/A	120	-5	65	75	N/A
89122700	17	13.5N	147.7E	11	67	198	N/A	105	0	60	65	N/A
89122706	18	13.4N	147.4E	0	165	194	N/A	90	0	40	40	N/A
89122712	19	13.5N	147.0E	46	209	259	N/A	65	10	20	25	N/A
89122718	20	14.0N	146.5E	120	328	N/A	N/A	45	10	10	N/A	N/A
89122800	21	14.8N	145.7E	237	N/A	N/A	N/A	30	0	N/A	N/A	N/A

7.2.2 NORTH INDIAN OCEAN

This section includes verification statistics for each warning in the North Indian Ocean during 1989. Pre- and post- warning best track positions are not printed, but are available on floppy diskettes by request.

JTWC FORECAST TRACK AND INTENSITY ERRORS BY WARNING

Tropical Cyclone 01B

	00h	24h	48h	72h
Average	23	106	N/A	N/A
# Cases	14	11	0	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WN ER	24 ER	48 ER	72 ER
89052312	1	18.1N	89.8E	30	169	N/A	N/A	30	0	10	N/A	N/A
89052318	2	18.7N	89.5E	11	135	N/A	N/A	30	0	5	N/A	N/A
89052400	3	19.4N	89.0E	28	188	N/A	N/A	30	0	-15	N/A	N/A
89052406	4	19.6N	88.6E	37	N/A	N/A	N/A	35	-5	N/A	N/A	N/A
89052412	5	19.6N	88.3E	32	139	N/A	N/A	35	-5	-15	N/A	N/A
89052418	6	19.5N	87.9E	37	78	N/A	N/A	40	-5	-5	N/A	N/A
89052500	7	19.5N	87.8E	13	71	N/A	N/A	45	0	-20	N/A	N/A
89052506	8	19.6N	87.8E	11	51	N/A	N/A	45	5	-20	N/A	N/A
89052512	9	19.8N	87.9E	29	26	N/A	N/A	45	-5	-10	N/A	N/A
89052518	10	20.2N	87.6E	11	55	N/A	N/A	45	0	-5	N/A	N/A
89052600	11	20.3N	87.5E	8	111	N/A	N/A	50	-5	0	N/A	N/A
89052606	12	20.7N	87.4E	45	139	N/A	N/A	50	-5	0	N/A	N/A
89052612	13	21.3N	87.3E	23	N/A	N/A	N/A	55	-10	N/A	N/A	N/A
89052618	14	21.9N	87.2E	8	N/A	N/A	N/A	50	5	N/A	N/A	N/A

Tropical Cyclone 02A

	00h	24h	48h	72h
Average	41	134	N/A	N/A
# Cases	5	1	0	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WN ER	24 ER	48 ER	72 ER
89061206	1	21.4N	65.7E	39	134	N/A	N/A	35	0	25	N/A	N/A
89061212	2	21.3N	64.9E	33	N/A	N/A	N/A	35	0	N/A	N/A	N/A
89061218	3	21.3N	64.2E	45	N/A	N/A	N/A	35	0	N/A	N/A	N/A
89061300	4	21.4N	63.8E	68	N/A	N/A	N/A	30	5	N/A	N/A	N/A
89061306	5	21.5N	63.4E	20	N/A	N/A	N/A	25	0	N/A	N/A	N/A

Tropical Cyclone 32W (Gay): **Please see page 237 for data.**

7.2.3 SOUTHERN HEMISPHERE

This section includes verification statistics for each warning in the South Indian and western South Pacific Oceans from 1 July 1988 to 30 June 1989. Pre- and post- warning best track positions are not printed, but are available on floppy diskettes by request.

JTWC FORECAST TRACK AND INTENSITY ERRORS BY WARNING

Tropical Cyclone 01S (Adelinina)

	00h	24h	48h
Average	83	235	384
# Cases	9	8	6

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WN ER	24 ER	48 ER
88110100	1	8.7S	76.7E	29	48	281	50	-5	0	-10
88110112	2	9.1S	76.6E	62	133	407	55	5	5	0
88110200	3	9.8S	76.7E	13	264	562	55	0	-10	-5
88110212	4	11.0S	77.6E	21	146	175	65	0	10	25
88110300	5	12.7S	79.0E	35	131	300	75	0	10	45
88110312	6	14.0S	80.4E	16	210	576	75	0	-10	-10
88110400	7	14.6S	81.7E	87	367	N/A	75	-10	-5	N/A
88110412	8	14.3S	82.7E	211	579	N/A	65	-20	-15	N/A
88110418	9	14.0S	83.2E	275	N/A	N/A	55	-30	N/A	N/A

Tropical Cyclone 02S (Barisaona)

	00h	24h	48h
Average	25	98	169
# Cases	26	24	22

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WN ER	24 WE	48 WE
88110806	1	6.9S	96.3E	24	25	90	45	-10	-15	-5
88110818	2	6.9S	95.4E	5	45	112	55	-5	5	15
88110906	3	6.9S	94.5E	0	78	130	55	0	10	20
88110912	4	6.7S	94.1E	13	74	131	55	0	10	20
88111000	5	6.3S	93.0E	5	26	48	55	0	-10	-25
88111012	6	6.1S	92.2E	23	37	96	55	-5	-10	-25
88111100	7	6.1S	91.2E	30	111	173	55	-5	-20	-25
88111112	8	6.4S	90.1E	18	90	156	55	-10	-25	-30
88111200	9	6.7S	88.4E	26	96	231	65	0	5	5
88111212	10	7.3S	86.6E	37	66	188	65	0	0	-30
88111300	11	7.9S	85.3E	23	169	308	65	0	-10	-40
88111312	12	9.2S	83.7E	18	166	259	65	0	-10	-25
88111400	13	10.1S	81.1E	76	104	97	65	0	-10	-5
88111412	14	10.4S	78.9E	30	96	193	75	0	5	0
88111500	15	11.0S	77.1E	36	136	186	85	-20	-25	-25
88111512	16	12.1S	75.0E	5	78	229	90	-10	-25	-40
88111600	17	12.9S	73.4E	25	72	139	95	-20	-25	-45
88111612	18	13.8S	71.8E	37	178	264	100	-5	-25	-35
88111700	19	14.4S	71.0E	55	116	194	90	-5	-15	-25
88111712	20	15.1S	69.8E	16	122	206	95	-10	-10	5
88111800	21	15.7S	68.9E	21	88	140	90	-5	-15	10
88111812	22	16.3S	68.3E	23	58	160	85	-5	15	25
88111900	23	17.1S	67.7E	12	32	N/A	80	0	30	N/A
88111912	24	17.9S	66.6E	49	283	N/A	50	10	5	N/A
88112000	25	18.4S	65.8E	33	N/A	N/A	40	5	N/A	N/A
88112012	26	18.5S	65.4E	5	N/A	N/A	30	0	N/A	N/A

Tropical Cyclone 03S (Ilona)

	00h	24h	48h
Average	14	106	203
# Cases	11	8	6

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
88121312	1	16.5S	120.0E	54	197	299	35	0	0	0
88121400	2	16.0S	117.9E	8	12	71	45	-5	-10	-15
88121412	3	16.1S	116.4E	12	132	269	50	0	0	-5
88121500	4	16.2S	115.8E	5	38	191	55	0	-5	-10
88121512	5	16.4S	115.4E	24	55	45	60	0	-15	-30
88121600	6	16.7S	115.1E	29	120	346	70	-5	-10	35
88121612	7	17.2S	115.1E	5	106	N/A	75	0	-10	N/A
88121700	8	18.3S	115.3E	16	183	N/A	85	0	35	N/A
88121706*	9	19.1S	115.7E	5	N/A	N/A	85	0	N/A	N/A
88121712	10	20.2S	116.0E	0	N/A	N/A	85	0	N/A	N/A
88121800	11	22.7S	117.0E	0	N/A	N/A	40	0	N/A	N/A

* Intermediate Update

Tropical Cyclone 04P (Delilah)

	00h	24h	48h
Average	20	74	110
# Cases	4	3	1

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89010118	1	18.7S	161.2E	38	106	110	45	-10	0	0
89010206	2	20.2S	165.0E	16	34	N/A	60	-20	-10	N/A
89010218	3	22.3S	167.8E	5	83	N/A	55	-20	-15	N/A
89010300	4	23.4S	168.8E	18	N/A	N/A	55	-20	N/A	N/A

Tropical Cyclone 05P (Gina)

	00h	24h	48h
Average	30	130	464
# Cases	6	4	2

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89010706	1	15.3S	172.1W	18	131	445	35	0	-10	0
89010718	2	16.4S	171.7W	29	131	483	40	0	5	20
89010806	3	17.6S	171.4W	8	112	N\A	45	-5	0	N\A
89010818	4	18.9S	171.1W	33	146	N\A	40	0	10	N\A
89010906	5	19.7S	172.8W	8	N\A	N\A	35	0	N\A	N\A
89010918	6	20.5S	175.1W	82	N\A	N\A	25	10	N\A	N\A

Tropical Cyclone 06S

	00h	24h	48h
Average	18	100	156
# Cases	9	7	5

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89011018	1	16.4S	40.9E	13	38	106	45	0	-10	-25
89011106	2	16.9S	41.2E	20	204	N\A	55	-10	-25	N\A
89011118	3	17.2S	41.6E	21	132	271	65	-10	-20	-45
89011206	4	17.3S	41.9E	12	69	111	65	0	15	15
89011218	5	17.5S	42.2E	26	38	156	75	-10	0	5
89011306	6	17.7S	42.6E	20	80	135	75	0	0	45
89011318	7	17.9S	42.8E	11	135	N\A	75	0	5	N\A
89011406	8	18.9S	43.8E	6	N\A	N\A	75	0	N\A	N\A
89011418	9	20.3S	44.6E	29	N\A	N\A	65	-10	N\A	N\A

Tropical Cyclone 07S (Edme)

	00h	24h	48h
Average	29	141	322
# Cases	11	10	8

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89012018	1	13.6S	82.9E	102	312	429	35	5	0	-10
89012106	2	14.0S	83.0E	17	132	182	45	0	-1	-30
89012118	3	15.0S	83.3E	5	17	12	50	0	-10	-40
89012206	4	16.4S	83.3E	33	147	369	65	-10	-35	-45
89012218	5	17.8S	82.8E	23	155	455	75	-10	-25	0
89012306	6	19.0S	82.0E	33	147	549	105	-10	10	40
89012318	7	19.5S	81.3E	20	174	267	115	0	50	75
89012406	8	20.7S	79.8E	23	73	317	105	0	25	40
89012418	9	22.3S	77.9E	28	77	N\A	75	0	25	N\A
89012506	10	23.5S	75.5E	33	172	N\A	55	-5	10	N\A
89012518	11	25.0S	72.5E	6	N\A	N\A	30	5	N\A	N\A

Tropical Cyclone 08S (Firinga)

	00h	24h	48h
Average	23	105	201
# Cases	14	10	9

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89012600	1	12.9S	66.1E	33	88	232	35	0	0	-15
89012612	2	14.3S	65.8E	21	109	234	40	0	-5	-25
89012700	3	15.2S	64.8E	5	134	232	45	0	-10	-30
89012712	4	16.4S	63.2E	32	149	212	55	-5	-10	-10
89012800	5	17.7S	60.9E	33	114	239	65	0	0	-10
89012806	6	18.2S	59.9E	8	50	129	70	0	0	0
89012818	7	19.6S	57.8E	16	87	169	90	0	20	40
89012906	8	20.5S	56.0E	28	121	156	90	5	5	15
89012918	9	21.6S	54.4E	23	98	208	85	0	15	10
89013006	10	23.0S	53.0E	108	N\A	N\A	65	5	N\A	N\A
89013018	11	24.3S	51.6E	8	100	N\A	50	10	5	N\A
89013106	12	25.9S	50.7E	6	N\A	N\A	45	-5	N\A	N\A
89013112	13	26.9S	50.5E	0	N\A	N\A	40	0	N\A	N\A
89020100	14	29.3S	50.3E	0	N\A	N\A	35	0	N\A	N\A

Tropical Cyclone 09S (Kirrily)

	00h	24h	48h
Average	27	162	313
# Cases	9	7	5

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89020612	1	14.5S	109.9E	17	143	297	35	0	5	25
89020700	2	15.8S	109.8E	8	55	212	50	-5	5	-20
89020712	3	16.8S	109.8E	12	82	279	50	0	0	-30
89020800	4	17.8S	109.7E	21	158	398	50	0	-25	-10
89020812	5	18.8S	109.3E	30	185	382	45	-45	-25	10
89020900	6	19.9S	108.0E	58	294	N\A	65	-65	-10	N\A
89020912	7	21.7S	106.8E	18	221	N\A	70	5	40	N\A
89021000	8	23.7S	105.1E	43	N\A	N\A	45	0	N\A	N\A
89021012	9	24.5S	103.1E	37	N\A	N\A	25	10	N\A	N\A

Tropical Cyclone 10P (Harry)

	00h	24h	48h
Average	23	111	269
# Cases	24	23	21

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89020800	1	17.3S	161.4E	24	157	281	30	5	-5	-15
89020812	2	18.3S	162.3E	28	198	307	45	0	-10	-55
89020900	3	18.2S	163.7E	66	156	283	55	-10	-30	-65
89020912	4	18.3S	165.0E	12	100	308	60	0	-35	-30
89021000	5	18.7S	165.6E	18	192	450	80	-5	-10	-5
89021012	6	19.3S	165.5E	13	155	348	110	0	20	45
89021100	7	20.1S	164.9E	5	112	306	115	0	5	0
89021106*	8	20.5S	164.4E	25	143	338	110	0	0	-20
89021112	9	20.9S	163.6E	5	145	352	105	-5	-10	-55
89021200	10	20.9S	162.5E	0	74	214	95	5	-5	-60
89021212	11	20.6S	161.5E	6	55	99	80	0	-30	-65
89021300	12	20.0S	160.6E	18	79	104	80	0	-40	-55
89021312	13	19.4S	159.7E	13	57	145	95	-5	-40	-5
89021400	14	19.2S	158.8E	24	74	221	115	0	20	30
89021412	15	19.0S	157.9E	5	92	248	130	0	25	35
89021500	16	19.3S	157.4E	11	152	376	120	-5	-10	10
89021512	17	19.5S	157.5E	24	158	426	115	-5	0	10
89021600	18	19.7S	157.7E	28	140	375	110	5	10	-5
89021612	19	19.8S	158.2E	11	96	237	95	0	-5	35
89021700	20	20.3S	159.5E	17	21	111	80	0	10	55
89021712	21	21.2S	160.9E	21	37	120	80	10	45	45
89021800	22	22.3S	162.6E	48	76	N\A	70	0	10	N\A
89021812	23	23.9S	163.9E	47	80	N\A	55	0	0	N\A
89021900	24	25.8S	165.4E	88	N\A	N\A	35	0	N\A	N\A

* Intermediate Update

Tropical Cyclone 11S (Hanitra)

	00h	24h	48h
Average	27	92	180
# Cases	23	21	19

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89021718	1	13.9S	96.9E	8	74	147	35	0	5	10
89021800	2	13.5S	95.8E	47	66	61	45	0	15	15
89021812	3	13.1S	93.6E	29	31	59	55	-10	15	-30
89021900	4	13.0S	91.3E	18	44	23	50	0	-10	-35
89021912	5	12.6S	89.0E	36	48	83	55	-5	-45	-45
89022000	6	12.7S	86.8E	24	80	216	75	-5	-20	-15
89022012	7	12.7S	85.3E	18	99	216	105	-15	0	-10
89022100	8	12.8S	84.1E	37	146	265	110	-20	-25	-50
89022112	9	12.9S	83.3E	13	96	133	115	-25	-25	-25
89022200	10	13.2S	82.8E	24	113	174	115	0	0	5
89022212	11	13.8S	82.4E	18	37	95	125	-35	-25	-20
89022300	12	14.6S	81.8E	8	91	213	125	-5	-20	-25
89022312	13	15.3S	80.7E	24	75	97	125	-10	-10	-10
89022400	14	16.2S	79.5E	5	33	111	120	-10	-10	-5
89022412	15	16.9S	78.1E	16	47	156	110	-5	5	5
89022500	16	17.9S	76.8E	37	143	387	105	-5	10	10
89022512	17	19.1S	75.4E	12	82	282	90	-10	-5	-5
89022600	18	20.4S	74.0E	28	166	402	80	-15	-20	-5
89022612	19	22.2S	72.7E	62	196	304	75	-10	0	5
89022700	20	24.9S	71.7E	37	140	N\A	65	-5	-5	N\A
89022712	21	28.0S	71.3E	26	121	N\A	55	5	10	N\A
89022800	22	30.7S	71.8E	78	N\A	N\A	45	0	N\A	N\A
89022806	23	31.7S	72.1E	15	N\A	N\A	35	0	N\A	N\A

Tropical Cyclone 12S (Gizela)

	00h	24h	48h
Average	33	154	266
# Cases	9	7	5

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89021812	1	15.8S	72.2E	117	125	114	45	-5	10	25
89021818	2	16.4S	72.1E	21	145	240	45	0	5	10
89021906	3	17.5S	72.0E	5	131	150	45	0	-10	5
89021918	4	18.1S	72.3E	6	62	293	60	-5	-10	15
89022006	5	19.1S	72.9E	25	189	533	65	5	15	25
89022018	6	20.7S	72.9E	42	266	N\A	65	0	20	N\A
89022106	7	21.6S	71.4E	33	162	N\A	50	5	15	N\A
89022118	8	22.1S	69.5E	23	N\A	N\A	40	15	N\A	N\A
89022206	9	23.8S	68.0E	21	N\A	N\A	30	5	N\A	N\A

Tropical Cyclone 13P (Ivy)

	00h	24h	48h
Average	50	120	207
# Cases	13	11	9

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89022318	1	17.5S	166.8E	57	196	367	30	5	15	10
89022406	2	18.0S	166.0E	29	199	400	35	0	5	0
89022418	3	18.9S	166.7E	17	127	98	40	5	-15	-45
89022506	4	19.5S	167.2E	0	82	212	50	-5	-15	-45
89022518	5	19.9S	167.6E	8	84	183	60	-5	-25	-15
89022606	6	20.2S	168.7E	18	74	88	70	20	25	15
89022618	7	20.9S	170.1E	16	87	176	90	5	25	35
89022706	8	21.5S	171.2E	6	21	157	90	0	-10	15
89022718	9	22.3S	171.9E	21	30	179	90	0	0	25
89022806	10	22.9S	172.7E	24	151	N\A	85	0	25	N\A
89022818	11	23.8S	172.8E	12	268	N\A	70	5	25	N\A
89030106	12	23.5S	171.4E	138	N\A	N\A	45	10	N\A	N\A
89030118	13	22.5S	170.4E	310	N\A	N\A	30	5	N\A	N\A

Tropical Cyclone 14P

	00h	24h	48h
Average	34	139	238
# Cases	11	9	6

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89022400	1	28.0S	137.4W	90	186	190	55	-15	-25	-40
89022412	2	27.0S	139.1W	12	145	204	65	0	10	25
89022500	3	26.7S	140.1W	22	139	194	80	-5	20	5
89022512	4	26.9S	140.6W	26	228	445	90	-10	10	25
89022600	5	28.0S	141.0W	24	185	273	80	-15	-20	0
89022612	6	29.6S	141.4W	72	44	123	75	-20	-20	-5
89022700	7	31.4S	141.8W	7	138	N\A	65	-15	-10	N\A
89022712	8	32.3S	141.2W	26	67	N\A	60	-10	-5	N\A
89022800	9	32.7S	140.3W	42	122	N\A	45	0	5	N\A
89022812	10	33.1S	139.5W	49	N\A	N\A	40	0	N\A	N\A
89030100	11	33.9S	138.4W	9	N\A	N\A	30	0	N\A	N\A

Tropical Cyclone 15P (Judy)

	00h	24h	48h
Average	22	160	390
# Cases	8	6	4

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89022400	1	21.5S	153.8W	34	139	218	35	0	-25	-40
89022412	2	22.9S	154.3W	6	266	568	55	0	-10	-30

Tropical Cyclone 15P (Judy) continued

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89022500	3	23.0S	155.2W	13	268	626	70	-5	-25	-20
89022512	4	22.7S	156.2W	21	89	148	80	-15	-10	25
89022600	5	22.4S	157.2W	28	47	N\A	90	-10	5	N\A
89022612	6	22.4S	158.3W	28	152	N\A	80	-10	30	N\A
89022700	7	22.8S	159.6W	16	N\A	N\A	75	-5	N\A	N\A
89022712	8	24.7S	160.4W	32	N\A	N\A	45	15	N\A	N\A

Tropical Cyclone 16S

	00h	24h	48h
Average	35	229	N\A
# Cases	3	1	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89022400	1	20.0S	117.3E	5	229	N\A	45	-10	15	N\A
89022412	2	21.9S	116.3E	94	N\A	N\A	30	5	N\A	N\A
89022500	3	23.6S	117.9E	6	N\A	N\A	25	-5	N\A	N\A

Tropical Cyclone 17S (Marcia)

	00h	24h	48h
Average	13	92	332
# Cases	3	2	1

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89030300	1	17.1S	100.1E	0	80	332	30	0	15	30
89030312	2	18.5S	98.7E	18	104	N/A	35	-5	20	N/A
89030400	3	19.7S	97.6E	23	N/A	N/A	30	0	N/A	N/A

Tropical Cyclone 18S

	00h	24h	48h
Average	40	220	185
# Cases	4	3	1

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89030906	1	23.9S	42.2E	63	163	185	35	0	5	10
89030918	2	26.4S	43.3E	30	228	N/A	35	0	0	N/A
89031006	3	28.9S	43.7E	37	270	N/A	35	0	0	N/A
89031018	4	30.4S	44.7E	31	N/A	N/A	30	0	N/A	N/A

Tropical Cyclone 19S (Jinabo)

	00h	24h	48h
Average	25	113	184
# Cases	13	11	3

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89032500	1	16.6S	52.7E	16	164	N/A	35	0	-30	N/A
89032512	2	18.0S	51.6E	29	167	N/A	55	0	-35	N/A
89032600	3	19.0S	51.2E	24	139	215	55	-5	-25	-20
89032612	4	19.5S	50.1E	24	112	N/A	65	-20	-35	N/A
89032618	5	19.9S	49.8E	32	81	N/A	65	0	-15	N/A
89032706	6	20.3S	49.4E	12	94	N/A	65	0	-10	N/A
89032718	7	20.8S	49.3E	50	N/A	N/A	60	-10	N/A	N/A
89032800	8	20.8S	49.4E	11	43	N/A	55	-5	-10	N/A
89032812	9	20.8S	49.4E	8	76	121	55	-5	10	10
89032900	10	20.9S	49.8E	53	158	215	45	0	5	5
89032912	11	21.0S	50.4E	5	42	N/A	35	5	10	N/A
89033000	12	21.5S	50.9E	21	168	N/A	30	5	5	N/A
89033012	13	23.2S	50.9E	40	N/A	N/A	25	5	N/A	N/A

Tropical Cyclone 20S (Ned)

	00h	24h	48h
Average	22	108	202
# Cases	19	15	11

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89032612	1	17.4S	115.0E	29	8	49	35	0	-5	-30
89032700	2	17.8S	113.5E	93	168	135	40	-5	-15	-40
89032706*	3	18.1S	112.7E	37	121	208	45	0	-20	-35
89032712	4	18.4S	111.8E	24	90	124	50	-5	-35	-30
89032718	5	18.8S	110.9E	17	95	118	55	-5	-40	-20
89032800	6	19.2S	110.2E	13	101	170	65	-10	-35	-5
89032806	7	19.5S	109.7E	8	94	220	75	-5	-30	5
89032812	8	19.9S	109.3E	5	108	246	90	-10	-5	45
89032818	9	20.3S	109.1E	37	173	347	100	-10	10	45
89032900	10	20.7S	109.0E	5	74	337	100	5	15	35
89032906	11	21.1S	109.0E	13	98	272	100	0	35	35
89032912	12	21.5S	108.9E	24	134	N/A	95	5	40	N/A
89032918	13	22.0S	108.8E	27	142	N/A	85	10	45	N/A
89033000	14	22.5S	108.7E	23	108	N/A	75	5	15	N/A
89033006	15	23.1S	108.5E	12	105	N/A	55	10	15	N/A
89033012	16	23.9S	108.4E	0	N/A	N/A	35	20	N/A	N/A
89033018	17	24.9S	108.5E	6	N/A	N/A	30	20	N/A	N/A
89033100	18	26.0S	108.7E	10	N/A	N/A	30	5	N/A	N/A
89033106	19	27.0S	109.3E	30	N/A	N/A	30	0	N/A	N/A

* 6-hourly warnings issued due to threat.

Tropical Cyclone 21S (Krissy)

	00h	24h	48h
Average	27	144	282
# Cases	18	17	16

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89033006	1	12.2S	73.0E	67	115	204	55	-15	-10	-25
89033018	2	12.4S	72.3E	13	26	146	60	-10	-15	-10
89033106	3	12.5S	71.5E	25	115	304	65	5	0	0
89033118	4	12.6S	70.7E	31	183	404	80	-10	-10	5
89040106	5	13.3S	70.1E	47	239	439	90	-20	-20	-20
89040118	6	14.3S	70.0E	40	108	153	100	-5	-5	-5
89040206	7	15.0S	70.2E	18	88	44	95	10	0	20
89040218	8	15.6S	70.5E	36	111	210	90	5	5	5
89040306	9	16.5S	70.4E	8	186	346	90	0	-5	-20
89040318	10	17.1S	69.2E	18	53	106	80	5	5	5
89040406	11	17.2S	67.4E	5	90	235	70	5	-15	-20
89040418	12	17.7S	65.8E	33	128	275	70	5	0	5
89040506	13	18.6S	63.7E	21	98	263	65	10	10	5
89040518	14	19.5S	61.4E	32	163	324	60	5	10	10
89040606	15	20.0S	58.6E	17	223	442	50	5	-10	0
89040618	16	21.8S	56.8E	50	191	616	45	10	10	0
89040706	17	23.4S	54.7E	33	332	N/A	45	0	5	N/A
89040718	18	24.5S	53.2E	0	N/A	N/A	35	0	N/A	N/A

Tropical Cyclone 22P (Kerry)

	00h	24h	48h
Average	56	158	386
# Cases	5	4	3

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89033100	1	19.3S	179.8W	57	131	303	30	5	0	-5
89033112	2	21.0S	177.5E	75	147	513	45	0	5	15
89040100	3	22.1S	177.4E	24	116	342	45	0	-10	-15
89040112	4	21.7S	177.6E	115	240	N/A	50	-5	-15	N/A
89040200	5	21.3S	177.6E	8	N/A	N/A	50	-20	N/A	N/A

Tropical Cyclone 23P (Aivu)

	00h	24h	48h
Average	27	108	172
# Cases	8	7	4

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89040100	1	10.3S	152.7E	18	158	209	35	0	-5	-35
89040112	2	11.8S	151.9E	31	167	190	45	0	-10	-45
89040200	3	13.9S	150.8E	16	54	112	60	0	-25	0
89040212	4	15.6S	149.6E	18	174	175	75	0	-60	-15
89040300	5	16.4S	149.2E	5	56	N/A	110	0	0	N/A
89040312	6	17.9S	148.8E	8	74	N/A	120	0	15	N/A
89040400	7	19.3S	147.7E	6	76	N/A	100	0	5	N/A
89040412	8	20.4S	145.9E	116	N/A	N/A	45	5	N/A	N/A

Tropical Cyclone 24S (Lezissy)

	00h	24h	48h
Average	64	260	455
# Cases	6	4	2

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89040612	1	11.9S	73.8E	74	300	512	40	-5	10	40
89040700	2	12.8S	72.1E	75	268	398	45	0	20	65
89040712	3	13.2S	71.8E	57	233	N/A	45	-10	5	N/A
89040800	4	13.5S	71.7E	130	237	N/A	45	0	20	N/A
89040812	5	14.2S	71.5E	42	N/A	N/A	35	5	N/A	N/A
89040900	6	15.5S	70.3E	8	N/A	N/A	25	0	N/A	N/A

Tropical Cyclone 25P (Lili)

	00h	24h	48h
Average	23	104	217
# Cases	9	8	8

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89040700	1	12.1S	162.2E	72	155	237	30	5	-5	-20
89040712	2	13.1S	163.9E	31	133	138	40	-5	-35	-50
89040800	3	13.8S	164.5E	18	88	150	60	5	-10	-10
89040812	4	14.4S	164.7E	17	102	285	80	0	-5	30
89040900	5	15.6S	164.6E	16	54	151	95	5	5	65
89040912	6	17.1S	164.6E	5	94	55	105	0	35	50
89041000	7	19.0S	165.0E	8	63	136	100	10	20	10
89041012	8	21.1S	166.2E	12	145	584	70	-5	20	15
89041100	9	23.1S	167.1E	24	N/A	N/A	35	0	N/A	N/A

Tropical Cyclone 26S (Orson)

	00h	24h	48h
Average	19	105	225
# Cases	12	9	7

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89041812	1	13.1S	123.7E	23	76	148	35	0	-10	-10
89041900	2	12.8S	122.3E	37	77	170	50	0	-20	-40
89041912	3	12.3S	121.0E	30	53	99	65	0	-10	-50
89042000	4	12.0S	119.9E	8	101	283	75	0	-15	-30
89042012	5	12.3S	118.7E	13	74	330	85	-5	-20	-35
89042100	6	13.4S	117.7E	21	51	186	105	0	5	0
89042112	7	14.6S	116.8E	29	64	362	115	0	-40	35
89042200	8	16.4S	116.3E	0	162	N/A	125	0	10	N/A
89042212	9	18.6S	116.3E	12	287	N/A	140	0	45	N/A
89042218*	10	20.1S	116.3E	16	N/A	N/A	125	0	N/A	N/A
89042300	11	22.0S	116.6E	12	N/A	N/A	100	0	N/A	N/A
89042306	12	24.1S	117.4E	26	N/A	N/A	75	0	N/A	N/A

* 6-hourly warnings issued due to threat.

Tropical Cyclone 27P (Meena)

	00h	24h	48h
Average	21	134	287
# Cases	16	15	12

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89050300	1	11.8S	161.3E	21	256	336	25	0	0	-10
89050312	2	11.1S	161.9E	24	102	288	30	0	0	-15
89050400	3	12.0S	161.3E	6	42	306	30	0	-10	-15
89050412	4	12.8S	161.2E	13	128	394	35	0	0	0
89050500	5	13.6S	160.3E	34	205	482	45	-5	-10	-10
89050512	6	14.7S	159.0E	11	187	N/A	45	-10	-15	N/A
89050600	7	15.6S	156.9E	16	164	337	45	-5	-5	0
89050612	8	14.7S	155.0E	74	290	408	45	0	0	0
89050700	9	13.4S	152.3E	25	66	330	40	-5	0	0
89050712	10	12.3S	150.3E	24	109	46	35	5	0	10
89050800	11	12.5S	148.8E	5	101	193	35	0	15	5
89050812	12	12.4S	146.8E	46	46	204	35	0	5	10
89050900	13	12.5S	143.3E	8	97	123	30	5	5	10
89050912	14	12.6S	141.8E	6	134	N/A	20	10	10	N/A
89051000	15	11.4S	138.7E	12	90	N/A	25	0	10	N/A
89051012	16	11.4S	136.9E	8	N/A	N/A	25	5	N/A	N/A

Tropical Cyclone 28P (Ernie)

	00h	24h	48h
Average	31	135	197
# Cases	9	7	5

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
89050706	1	12.4S	169.9E	29	21	25	30	0	5	20
89050718	2	12.4S	167.3E	37	124	146	30	0	10	25
89050806	3	11.9S	164.9E	33	88	206	35	0	10	20
89050818	4	11.9S	162.4E	5	97	247	30	5	10	0
89050906*	5	12.6S	160.1E	18	N/A	N/A	30	0	N/A	N/A
89051018	6	12.4S	151.5E	77	246	362	30	0	15	25
89051106	7	12.5S	150.8E	41	289	N/A	30	-5	0	N/A
89051118	8	12.7S	150.6E	11	76	N/A	30	0	5	N/A
89051206	9	12.6S	150.2E	30	N/A	N/A	30	-5	N/A	N/A

* Regenerated

APPENDIX A
DEFINITIONS

BEST TRACK - A subjectively smoothed path, versus a precise and very erratic fix-to-fix path, used to represent tropical cyclone movement.

CENTER - The vertical axis or core of a tropical cyclone. Usually determined by cloud vorticity patterns, wind and/or pressure distribution.

EPHEMERIS - Position of a body (satellite) in space as a function of time; used for gridding satellite imagery. Since ephemeris gridding is based solely on the predicted position of the satellite, it is susceptible to errors from vehicle wobble, orbital eccentricity and the oblateness of the Earth.

EXPLOSIVE DEEPENING - A decrease in the minimum sea-level pressure of a tropical cyclone of 2.5 mb/hr for 12 hours or 5.0 mb/hr for six hours (Dunnavun, 1981).

EXTRATROPICAL - A term used in warnings and tropical summaries to indicate that a cyclone has lost its "tropical" characteristics. The term implies both poleward displacement from the tropics and the conversion of the cyclone's primary energy source from the release of latent heat of condensation to baroclinic processes. It is important to note that cyclones can become extratropical and still maintain winds of typhoon or storm force.

EYE - The central area of a tropical cyclone when it is more than half surrounded by wall cloud.

FUJIWHARA EFFECT - A binary interaction where tropical cyclones within about 750 nm (1390 km) of each other begin to rotate about one another. When tropical cyclones are within about 400 nm (740 km) of each other, they may also begin to be drawn closer to one another (Brand, 1970) (Dong and Neumann, 1983).

INTENSITY - The maximum sustained 1-minute mean surface wind speed, typically within one degree of the center of a tropical cyclone.

MAXIMUM SUSTAINED WIND - The highest surface wind speed averaged over a one-minute period of time. (Peak gusts over water average 20 to 25 percent higher than sustained winds.)

RAPID DEEPENING - A decrease in the minimum sea-level pressure of a tropical cyclone of 1.25 mb/hr for 24-hours (Holliday and Thompson, 1979).

RECURVATURE - The turning of a tropical cyclone from an initial path toward the west and poleward to east and poleward.

SIGNIFICANT TROPICAL CYCLONE - A tropical cyclone becomes "significant" with the issuance of the first numbered warning by the responsible warning agency.

SIZE - The areal extent of a tropical cyclone, usually measured radially outward from the center to the outermost closed isobar.

STRENGTH - The average wind speed of the surrounding low-level wind flow, usually measured within one to three degrees of the center of a tropical cyclone.

SUBTROPICAL CYCLONE - a low pressure system that forms over the ocean in the subtropics and has some characteristics of a tropical circulation, but not a central dense overcast. Although of upper cold low or low-level baroclinic origins, the system can transition to a tropical cyclone.

SUPER TYPHOON - A typhoon with maximum sustained 1-minute mean surface winds of 130 kt (67 m/sec) or greater.

TROPICAL CYCLONE - A non-frontal, migratory low-pressure system, usually of synoptic scale, originating over tropical or subtropical waters and having a definite organized circulation.

TROPICAL DEPRESSION - A tropical cyclone with maximum sustained 1-minute mean surface winds of 33 kt (17 m/sec) or less.

TROPICAL DISTURBANCE - A discrete system of apparently organized convection, generally 100 to 300 nm (185 to 555 km) in diameter, originating in the tropics or subtropics, having a non-frontal, migratory character and having maintained its identity for 12- to 24-hours. It may or may not be associated with a detectable perturbation of the wind field. It is the basic generic designation which, in successive stages of development, may be classified as a tropical depression, tropical storm, typhoon or super typhoon.

TROPICAL STORM - A tropical cyclone with maximum sustained surface winds in the range of 34 to 63 kt (17 to 32 m/sec) inclusive.

TROPICAL UPPER-TROPOSPHERIC TROUGH (TUTT) - A dominant climatological system and a daily upper-level synoptic feature of the summer season, over the tropical North Atlantic, North Pacific and South Pacific Oceans (Sadler, 1979).

TYPHOON (HURRICANE) - A tropical cyclone with maximum sustained 1-minute mean surface winds of 64 to 129 kt (33 to 66 m/sec). West of 180 degrees longitude they are called typhoons and east of 180 degrees longitude hurricanes.

WALL CLOUD - An organized band of cumuliform clouds that immediately surrounds the central area of a tropical cyclone. The wall cloud may entirely enclose or partially surround the center.

APPENDIX B
NAMES FOR TROPICAL CYCLONES (EFFECTIVE AFTER TY WAYNE (25W) 1989)

Column 1	Column 2	Column 3	Column 4
ANGELA	ABE	AMY	AXEL
BRIAN	BECKY	BRENDAN	BOBBIE
COLLEEN	CECIL	CAITLIN	CHUCK
DAN	DOT	DOUG	DEANNA
ELSIE	ED	ELLIE	ELI
FORREST	FLO	FRED	FAYE
GAY	GENE	GLADYS	GARY
HUNT	HATTIE	HARRY	HELEN
IRMA	IRA	IVY	IRVING
JACK	JEANA	JOEL	JANIS
KORYN	KYLE	KINNA	KENT
LEWIS	LOLA	LUKE	LOIS
MARIAN	MIKE	MIREILLE	MARK
NATHAN	NELL	NAT	NINA
OFELIA	OWEN	ORCHID	OMAR
PERCY	PAGE	PAT	POLLY
ROBYN	RUSS	RUTH	RYAN
STEVE	SHARON	SETH	SIBYL
TASHA	TIM	THELMA	TED
VERNON	VANESSA	VERNE	VAL
WINONA	WALT	WILDA	WARD
YANCY	YUNYA	YURI	YVETTE
ZOLA	ZEKE	ZELDA	ZACK

NOTE: Names are assigned in rotation and alphabetically. When the last name in Column 4 (ZACK) has been used, the sequence will begin again with the first name in Column 1 (ANGELA).

SOURCE: CINCPACINST 3140.1T

NAMES FOR TROPICAL CYCLONES (PRIOR TO TY ANGELA (26W) 1989)

Column 1	Column 2	Column 3	Column 4
ANDY	ABBY	ALEX	AGNES
BRENDA	BEN	BETTY	BILL
CECIL	CARMEN	CARY	CLARA
DOT	DOM	DINAH	DOYLE
ELLIS	ELLEN	ED	ELSIE
FAYE	FORREST	FREDA	FABIAN
GORDON	GEORGIA	GERALD	GAY
HOPE	HERBERT	HOLLY	HAL
IRVING	IDA	IAN	IRMA
JUDY	JOE	JUNE	JEFF
KEN	KIM	KELLY	KIT
LOLA	LEX	LYNN	LEE
MAC	MARGE	MAURY	MAMIE
NANCY	NORRIS	NINA	NELSON
OWEN	ORCHID	OGDEN	ODESSA
PEGGY	PERCY	PHYLLIS	PAT
ROGER	RUTH	ROY	RUBY
SARAH	SPERRY	SUSAN	SKIP
TIP	THELMA	THAD	TESS
VERA	VERNON	VANESSA	VAL
WAYNE	WYNNE	WARREN	WINONA

APPENDIX C

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APPENDIX D

PAST ANNUAL TROPICAL CYCLONE REPORTS

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19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

ANNUAL PUBLICATION SUMMARIZING TROPICAL CYCLONE ACTIVITY IN THE WESTERN NORTH PACIFIC, BAY OF BENGAL, ARABIAN SEA, WESTERN SOUTH PACIFIC AND SOUTH INDIAN OCEANS. A BEST TRACK IS PROVIDED FOR EACH SIGNIFICANT TROPICAL CYCLONE. A BRIEF NARRATIVE IS GIVEN FOR ALL TROPICAL CYCLONES IN THE WESTERN NORTH PACIFIC AND NORTH INDIAN OCEANS. ALL RECONNAISSANCE AND FIX DATA USED TO CONSTRUCT THE BEST TRACKS ARE PROVIDED, UPON REQUEST, ON FLOPPY DISKETTES. FORECAST VERIFICATION DATA AND STATISTICS FOR THE JOINT TYPHOON WARNING CENTER (JTWC) ARE SUBMITTED.

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